SCIENTIFIC AMERICAN MONTHLY

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CUTTING THE COCOANUT CAKE—PHILIPPINE NATIVES HAULING COCOANUTS TO THE MILLS. (SEE PAGE 404)

SCIENTIFIC AMERICAN MONTHLY

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OUR APPLE.

WHAT do we know about the planet we live upon? We have determined its shape; we have measured its size; we have estimated its weight; we have climbed its mountain peaks and delved into its ocean depths; we have winged our way up into the envelope of the atmosphere and soared far above the clouds, and we have bored far into the ground, but there are lofty heights that have not yet been scaled, profound depths that have not been sounded, and vast areas that have not yet felt the tread of human foot. Undoubtedly it is only a question of time when all these regions will yield to the zeal of the explorer. However, then we shall have but a superficial acquaintance with the earth. In some respects we know more about the sun than we do about our own planet. We have actually discovered elements on the sun before they were found here on the earth. At best our knowledge of the earth is not even skin deep.

The skin of an apple measures in the neighborhood of a hundredth of an inch in thickness. The apple—a large one—is, say, four inches in diameter. Enlarge it to the diameter of the earth and the skin will measure about twenty miles in thickness. What do we know about the skin of our apple?

The deepest well ever bored is on the Lake farm near Fairmount, West Virginia. It is a hole six inches in diameter, which was driven to a depth of 7579 feet, or nearly a mile and a half, before a slide of earth stopped further boring. The deepest mine shaft in the world is at Morro Velho, Brazil, which goes down to a depth of 6400 feet below the surface, or approximately one mile and a fifth. So far we have barely begun to gnaw through the skin of the earth. What do we know of the meat of this apple?

We assume that the center of the earth is hot, very hot indeed. Samples of the earth's interior are hurled out of volcanoes, or pour as molten lava from the lips of craters, but we can only guess at the depth from which this material comes. We doubt that the core of the earth is molten.

We know that as we dig into the earth the temperature rises, but the rise of temperature is not regular; it varies with different localities. In the Lake well referred to above a temperature of 168.6 degrees Fahrenheit was observed at a depth of 7500 feet. It is assumed that the boiling point would be reached at a depth of about 10,000 feet.

Because we know so little of the interior of the earth it has been suggested that explorations be conducted into the interior of the earth for the purpose of obtaining scientific information. Some years ago Sir Charles A. Parsons proposed that a shaft be dug to a depth of twelve miles. It was objected at the time that the enormous pressure of the earth would make it difficult, if not impossible, to dig such a shaft. When the aqueduct siphon was bored through solid granite under the Hudson River to a depth of 1200 feet special measures had to be taken to protect the workmen from large flakes of rock which were constantly breaking off with a snap like that of a pistol report. This flaking was due to the release of pressure on the rock which had been under enormous compressive strains for ages. Undoubtedly difficulties of that sort would be encountered in boring a twelve-mile shaft. It was even suggested that the surrounding pressure would actually close the bore. However, small scale experiments have been made with high pressures and temperatures which indicate that such would not be the case and it is probable that the full diameter of the bore could be maintained until so great a depth had been attained that the combined heat and pressure would render the rock plastic and cause it to flow into the bore. This would certainly not take place at a depth of less than thirty miles. No doubt the greatest obstacle to be overcome would be that of high temperature. Special cooling apparatus would be required to reduce the heat sufficiently to enable the workmen to perform their labors.

The subject is discussed by Sir Charles A. Parsons in the article on High Temperatures and Pressures on page 432. When he first proposed digging such a shaft he estimated that it would require about eighty years to complete the work. Since then excavating machinery and methods have been improved to such an extent that it seems probable that such a shaft could be sunk in thirty years.

The lessons that we should learn from such an undertaking would be of untold value to science. It is quite possible new light would be thrown upon the composition of chemical elements. We might learn something about the transmutation of metals in Nature's laboratory down in the bowels of the earth.

Not only would the shaft be of interest to science, but it is quite probable that it would prove of commercial value. Those who have bewailed the fact that we are fast exhausting our stores of coal and oil and have been holding forth a gloomy prospect for posterity may be reminded that there are vast stores of heat confined within the earth which have not yet been tapped. Even now some use is being made of the internal heat of the earth in certain volcanic regions of Italy, where the steam issuing from the ground is trapped and put to work. It has been proposed that bores be sunk into the ground to admit water which would be converted into steam, and then converted into mechanical work. There are untold stores of energy under our very feet waiting to be developed by future generations. Undoubtedly there are vast deposits of minerals still to be exploited and it may be that there are materials rich in value yet to be discovered and put into the service of man.

It is well worth our while to explore the skin of the apple we live upon.

Celestial Photography for Amateurs*

Excellent Results Obtained With Crude Apparatus

By Dean B. McLaughlin

As a rule, I believe that amateur astronomers have, on the whole, remained aloof from the field of celestial photography. This is probably not because they have no inclination to apply photography to their work, but because they do not realize the full power of their instruments. They are apt to think that their telescopes can accomplish nothing in this line. It is the purpose of this article, therefore, to show just what results can be obtained with the smallest and crudest of apparatus. The reader should bear in mind that the largest instrument I have ever used for photography is a 2¼-inch telescope of 34-inch focal length.

In February, 1915, I experimented with a No. 2 Brownie camera and found that with the instantaneous exposure of its shutter, it was possible to obtain very good pictures of the moon. Although only a millimeter in diameter, these images show all the naked-eye details of the moon. I then constructed the lunar camera with which the accompanying photographs were obtained (Figs. 2 and 4).

This is a light-proof wooden box about five inches square and six inches deep (Fig. 1). The front of the box is double. In the first thickness of wood there is a hole large enough to admit the eye-piece end of the telescope. The next thickness is pierced with a hole as large as the rear lens of the eye-piece. Back of this hole is the shutter, which consists of a slip of cardboard with a hole in it. The exposure is made by allowing this hole to pass by the eye-piece. This shutter is operated by a rubber band, which is perhaps the simplest and most efficient shutter spring for such a camera. The back is open and carries a ground glass screen. There is an opening to accommodate a four by five plate-holder. The principle employed in this apparatus is that of *projection*, i.e., the image of the moon is projected on the plate, just as the solar image is projected on a screen for the study of sunspots. (See Fig. 1).

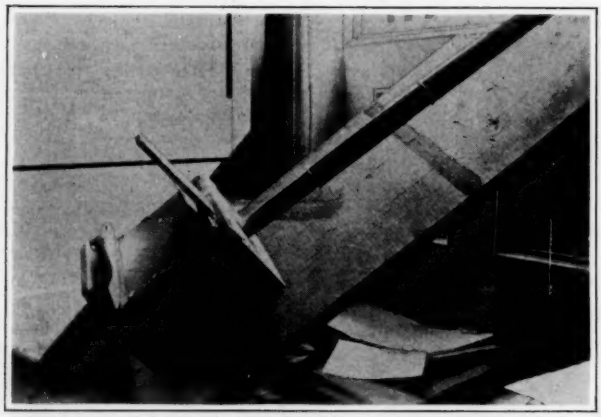


FIG. 1. SMALL TELESCOPE FOR LUNAR AND SOLAR PHOTOGRAPHY

For some time I used a small telescope of the type popularly known as a "spy-glass." A lunar image about 22 mm. in diameter was obtained with an exposure of half a second. The negatives thus taken were rather thin and did not show objects on the terminator. Later, using the 2¼-inch telescope, denser negatives were obtained somewhat smaller than the first. These showed many details on the terminator, but this topic will be discussed later.

*Reprinted from *Popular Astronomy*, February, 1920.

The telescope and camera are securely mounted on a board. It may be propped against any handy object. Of course, with this arrangement, it is impossible to follow the moon. The apparent motion per second, due to the rotation of the Earth is:

$$m'' = 15'' \cos \delta$$

where δ is the declination of the moon. Since the moon is never as much as 29° from the Equator, its minimum motion is more than 13″ per second. Therefore, with the telescope at

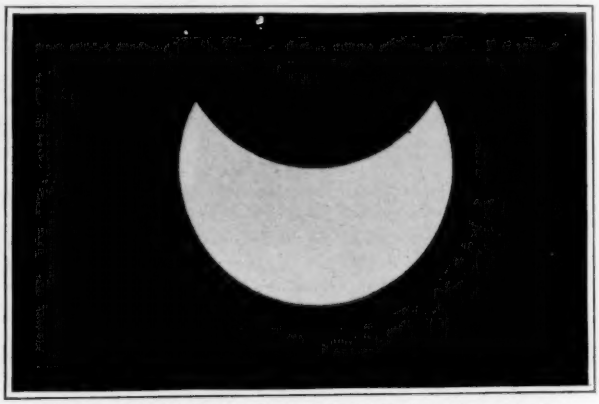


FIG. 2. SOLAR ECLIPSE AT NEW YORK, JUNE 8, 1918. 11H. 06M. G.M.T.

rest, an exposure of more than half a second would materially injure the smaller details. The farther the plate is from the eye-piece, the larger will be the image obtained; but the larger the image, the thinner will be the negative. From experience I have found that it is best to make the diameter of the image *one-third of the aperture of the telescope.* Thus, with a 2¼-inch instrument, I make the image of the moon about ¾ inch in diameter.

When photographing the sun, I use my "spy-glass" and obtain a much larger image. My greatest difficulty has been in obtaining a short enough exposure. When taking a solar photo, the shutter is allowed to drop as fast as the rubber band can move it. When photographing the moon, it is lowered slowly with the hand.

The prints can never do justice to the original negatives. The nearest to perfect prints are a few lantern slides which a friend made from my negatives. To give an idea of the delicate details obtained with this seemingly insignificant apparatus, I will summarize a catalogue which I made of the craters found on the plates by careful microscopic examination. On first examination of 32 plates, a total of 51 craters, whose names I knew, were found. A second examination resulted in listing 11 more. These craters ranged from Clavius down to craters twenty miles in diameter. Many unnamed craters only ten miles in diameter were found. Some appeared only once, but many were found on four or five plates. In addition to this, a photograph of Venus in the crescent phase was obtained. The crescent was distinct under the microscope. The image was only a third of a millimeter in diameter.

Since my telescopes are not mounted equatorially and have no driving clock, it would appear that the photography of the stars is impossible with my equipment. However, I was able to convert my tripod into an equatorial mounting by re-adjusting the legs. As for the driving clock, the hand is a fair substitute.

The stellar camera (Fig. 3) consists of a cardboard box, at the front of which is a common *reading-glass*. The shutter is a sheet of cardboard before the lens and is raised and lowered by means of two strings. The camera is strapped to the tube of the telescope. It is evident that if a star be

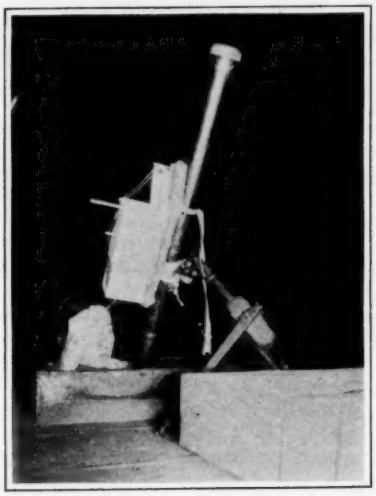


FIG. 3. STELLAR CAMERA MOUNTED ON TELESCOPE TUBE

followed so as to remain in the field of the telescope, that star will occupy a nearly fixed position on the sensitive film. To keep it as accurately in one place as is possible with such an instrument, a pair of cross-threads is placed between the lenses of a negative eye-piece. The star image is thrown out of focus so as to obtain a small disk on which the cross-threads stand out clearly. A Premo film pack is used because small enough plates could not be obtained.

The operation with this instrument is as follows: First, the film pack is placed in position, the focus having been found. Then a bright star in the region to be photographed is selected and its image brought to the intersection of the cross-threads. Then, *and not until then*, the shutter is opened and the star is followed so as to remain at the intersection of the threads. If by any chance it escapes from the field, the shutter is closed at once. The following of the star in this manner is nervous work. I have never been able to continue it for more than ten minutes. A total exposure of half an hour or more should be given for most photographs.

Of course there are numerous disadvantages. First, if the telescope is not accurately mounted as an equatorial, the star may leave a trail, although this will never be very long. Secondly, the reading-glass lens is not corrected for spherical aberration. If a camera with a wide lens, such as the Graflex, is available, it should be used by all means. If a driving clock is used, the photographer should, nevertheless, remain at the eye-piece to correct any irregularities of motion. Figs. 5 and 6 were obtained with the apparatus described above.

The negative of Fig. 5 shows more than 20 stars and that of Fig. 6 shows over 40.

Lastly, we come to the use of the hand camera. The two series of photographs shown in Figs. 7 and 8 were obtained by leaving the camera in one position until it became necessary to start a new row. At intervals of five minutes or so, photographs were taken. Fig. 7 was over-exposed. Fig. 8 was taken with the lens stopped down to little more than a pinhole and giving an exposure of 1/50 second. Both were taken with a No. 2 Folding Brownie.

Concerning the results that may be obtained with various instruments, I will say that I do not believe it beyond the power of a three-inch telescope to obtain recognizable photographs of Saturn and his rings, provided the telescope has a good driving clock and is equatorially mounted. Other good objects for such an instrument would be Jupiter and his satellites and Venus, in all her phases. Two or three minutes' exposure should be given for Jupiter's moons.

There are a few points which it will be well for a beginner in celestial photography to bear in mind:

1. Don't sacrifice density in the negative, for the sake of obtaining a large picture.

2. Don't try to photograph the moon through a thin film of cloud. The cloud absorbs a large proportion of the blue end of the spectrum.

3. The same applies to any heavenly body when near the horizon.

4. Remember that the intensity of light varies inversely as the area over which it is spread.

FIG. 4. THREE PHOTOGRAPHS OF THE MOON

5. Don't expose more than half a second unless a driving clock is used.

I have found the Stanley dry plate, manufactured by the Eastman Kodak Company, perfectly satisfactory for all my work.

INTERNATIONAL COMMITTEE ON STELLAR PARALLAXES.

AT the initial meeting of the International Astronomical Union, held in Brussels last July a committee on Stellar Parallaxes was appointed. All institutions in the United States which are actively engaged in stellar parallax work are represented in the membership of this committee and thus the corresponding committee of the American Astronomical Society appears to have become superfluous.

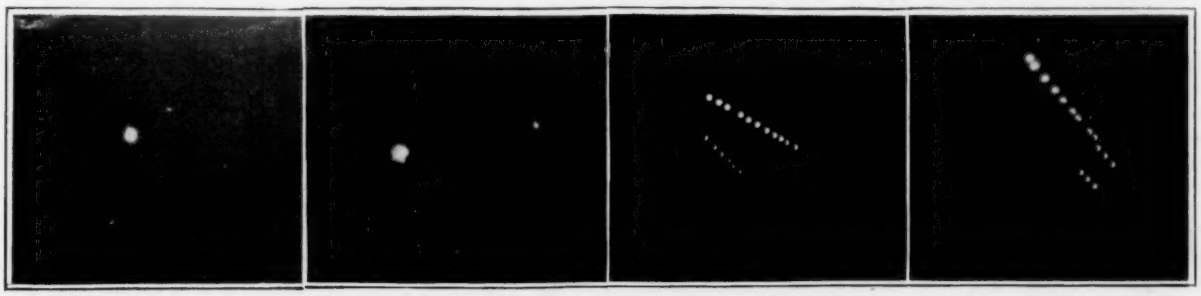


FIG. 5. ALTAIR AND VICINITY. EXPOSURE 25 MINUTES

FIG. 6. PHOTOGRAPH OF X AND Y CYGNI. EXPOSURE 10 MINUTES

FIG. 7. SERIAL PHOTOGRAPH OF LUNAR ECLIPSE, JAN. 7-8, 1917

FIG. 8. SERIAL PHOTOGRAPH OF SOLAR ECLIPSE, JUNE 8, 1918

Will o' the Wisp—Ignis Fatuus—Irrlichter—Feux Follet

Interesting Records of This Curious Phenomenon

By Rich D. Whitney, Assoc. Prof. of Electrical Engineering, Syracuse University

THE phenomenon known as the Will o' the Wisp is one of whose origin little is known and of whose occurrence few authentic records are available. The appearance of this phenomenon is of such a nature as quite to unnerve the ordinary observer and cause his imagination to run riot with the result that few facts are really known. Among the ignorant and superstitious, the will o' the wisp is thought to be due to the evil one and its antics often seem to bear this out.

In getting together the material for this article, the author has searched out all probable sources of information on the subject to be found in English, French, Italian and German. The absence of the subject from scientific writings is conspicuous. The longest treatise on the subject was found in the American Encyclopedia which was published in 1808 at a time when the fluid theory of electricity was the most accepted one.

Professor Besel, a German scientist, writing in *Annalen der Physik*, Vol. XLIV, page 366, tells of an experience which he had in the neighborhood of a great swamp in the Duchy of Bremen along the river Wörpe, December 2, 1807. The phenomenon was observed by him in the morning hours of a dark, calm night after a light rain had fallen occasionally throughout the night. The professor was aboard a boat and learned that the phenomenon was common in that locality but of sufficient distance away so that the skipper of the boat was not disturbed by it. The place of occurrence was a peat bed which was continuously dug over by the peasants of the neighborhood. Numerous little flames seemed to stand over water puddles among the bogs. After glowing for some time they would disappear. The color of the flame was somewhat bluish like that of impure hydrogen gas. Their light power must have been inconsiderable as he was unable to see that the ground in the immediate vicinity was noticeably illuminated or that the large numbers of them spread abroad any noticeable light. Professor Besel estimated the number of such flames visible at any time as about one hundred and their duration about fifteen seconds. Some of the flames seemed fixed, others moved horizontally and whole groups were observed to float about like flocks of flying birds. The flames seemed to remain in the lower portions of the bogs. The professor suggested that an expedition be formed to investigate the locality and the appearance of the "Irrlichter" but no such expedition was later recorded.

In a translation from the Italian, the following incidents were recorded: A certain painter was passing along the streets of Bologna at night when he saw a fiery ball come out from between the flag stones of the street almost between his feet, run along the ground, arise to some height and vanish. He felt the heat on his face as the ball passed near him. He reported the phenomenon to another gentleman who made an extensive study of the locality and the appearance of the will o' the wisp, going from place to place and making lengthy observations. He observed on both clear and cloudy nights. This gentleman said that the phenomenon was generally supposed to be connected with decaying animal matter and to originate many times in grave yeards. He remained at church yard entrances a great deal but never saw one there. These investigations were carried out in late autumn, a time when this fiery phenomenon happens to show itself more frequently than at any other time, according to the published reports. He found this to be true and attributed it to the quick changes in the depth of the atmosphere which allowed the gases held in the earth to respond to their natural elasticity and find an exit. He observed only three will o' the wisp phenomena and each on a different night.

The first came out of the earth, arose to a height of ten to fifteen feet and with a slight report disappeared. The second moved horizontally, was followed by the investigator until it was borne over a river by the wind and disappeared. The third brought the opportunity for an experiment which the observer had tried to make before but without success. He carried out the experiment in the parish of St. Domino near the little church "Ascension," about two miles from Bologna. This church was near a brook in which years before three silver offering bowls of beautiful old Roman work had been found. This region was especially rich in will o' the wisp. The peasants thereabouts were superstitious and believed these flames to be the burnings of souls. He had spent several evenings there in vain but on the night following what is called there the "Northern Light Night" in October, he was rewarded. He was tired from traveling and stopped at the house of the peasant in whose field the lights were said to appear. He opened the window which looked out upon the field and toward eleven o'clock the much desired light appeared. With a stick on the end of which was fastened a piece of easily ignitable oakum, he rushed to the place while the peasants flocked to the windows and doors. When within about twenty steps of the light he stopped to observe it. It had the form and color of an ordinary flame but had a light smoke. It was almost five inches thick and moved slowly forward from the south to the north. Upon his approach, it changed its direction, increased its distance from him and arose. By a very quick motion with the stick, he was able to pass the oakum through the flame and the former instantly ignited and by swinging it above his head, the peasants distinguished the flame from that of the phenomenon. Soon the will o' the wisp went out at a height of twelve to eighteen feet. It reappeared (if it was not another) but was much smaller and at a distance. The observer ran toward where it appeared but it went out and he was never able to see any others in that locality again. The ashes of the oakum did not smell as phosphorous does but had a very peculiar and strong odor which he thought was not unlike ammonia and sulphur.

Herr Vogel, an astronomer of Leipzig, observed this phenomenon twice. He first saw the will o' the wisp in Saxony on a dark rainy night of September, 1849, when he was journeying between two cities with friends. Two or three hundred feet from the road there was a swampy tract of land on which little flames were to be seen. The neighboring peasants declared this phenomenon to be common in that locality. In November of the same year he observed will o' the wisp in great quantity just outside of one of the gates of Leipzig. He went to the palace to investigate on a cold, bright evening. The ground on which the flames appeared was not very large, was damp and had been recently threaded with small ditches. After some time he saw a faint light in one of these ditches and saw a little flame about as bright as the glow of a lightly rubbed match gives out, and its brilliancy very similarly increased and decreased. It came and went with a period of about three seconds. This he observed for several minutes and was able to detect no odor or smoke. The flame lighted about three inches of the bottom of the ditch and was about one inch in height. Herr Vogel believed the phenomenon exactly like that he had previously seen except that in the first case the flames were much more numerous so that they had almost the appearance of moonlight on water in motion. He could detect no motion of the flame but when one went out and another came in its place it had the appearance of motion. A railroad guard told Herr Vogel that a quantity of glow worms had recently covered that ground.

From the French Encyclopedia, some of the following facts were taken: "Will o' the wisp are irregular lights which can be seen plainly at night around cemeteries and marshy places. The will o' the wisp has the aspect of a flame terminated by an aigrette which resembles the crown of a bird. It is visible especially in the autumn at calm times. This apparition is an object of fright for the peasants who believe they see a soul in pain. All contemporary works consider this phenomenon a luminous exhaling and the chemists are of the same mind. According to the latter the phenomenon proves organic matter in decomposition which gives off large bubbles of hydrogen phosphorous gas which is rendered spontaneously inflammable in the air by a small quantity of hydrogen phosphorous liquid. This explanation seems true as to the substance of the will o' the wisp as witnessed by the odor of phosphorous which the phenomenon leaves for some time after it has disappeared but does not coincide exactly with the facts. In reality the will o' the wisp will burn for ten, twenty or thirty seconds and rarely for several minutes and does not produce smoke, set things on fire, or even heat the herbs on which it rests. It must necessarily be admitted that, in the gas which makes up the 'feux follet,' the proportion of hydrogen phosphorous liquid is very slight to cause the spontaneous flaming up in the air and also that the phenomenon shines by phosphorescence only."

Another occurrence of these phenomena was reported as having occurred on Sunday, December 22, 1839, between five and nine o'clock in the evening on the streets of Fontainbleau in France. The weather was calm and rainy and phosphorescent flames arose from muddy puddles in many streets of the city and produced upon leaving the water a crackling noise. Wherever these flames were observed, the air seemed to be filled with a thick phosphorous smoke. Stirring the water in the puddles increased the number of flames which appeared.

From the American Encyclopedia the facts given in this paragraph were obtained: "Benighted travelers are sometimes said to have been misled into marshy places by the will o' the wisp which they thought were candles at a distance. The will o' the wisp are frequent about burying places and dung hills and certain countries are remarkable for the occurrence of this phenomenon, especially Italy, Spain and Ethiopa. It avoids the approach of anyone and flits from place to place as if animated. A certain Dr. Derham was able to get so near to a will o' the wisp that he had a very advantageous view of it. This was in some boggy ground between two rocky hills. It was a dark, calm night and he was able to advance within two or three yards of it. It appeared as a complete undivided body of light so that it could not have been occasioned by insects, and it kept dancing about a dead thistle. On his near approach it jumped to a new place and kept flying before him as he moved."

Monsieur Baccari learned that two of these lights appeared in the plains about Bologna, one north, the other south of that city and were to be seen almost every dark night. One of these appeared to a gentleman of his acquaintance as he was traveling. It moved constantly before him for about a mile and gave a better light than a torch. Both of these lights were reported as giving a very strong light and were constantly in motion. Sometimes they would rise, sometimes sink, but as a rule would hover about six feet above the ground. They would also disappear frequently and suddenly reappear in some other place. They differed also in size and shape, sometimes spreading wide, and then contracting, sometimes breaking into two parts and then joining again. They would at times appear like waves, at others sparks would seem to fall from them. They were but little affected by the wind and in wet and stormy weather they were frequently observed to cast a stronger light than in dry weather. They were also observed more frequently when snow lay upon the ground than in the hottest summer. The ground near Bologna where the largest of these lights was observed is a hard chalky soil mixed with clay, which retains moisture long, but breaks and cracks in hot weather. On the mountains where the soil is more loosely held together the will o' the wisp were not seen as often but seemed to choose regions near rivers or brooks.

Another record given by M. Baccari is as follows: "An intelligent gentleman traveling in the evening between six and nine o'clock on a mountainous road about ten miles south of Bologna, perceived a light which shone very strangely upon some stones near water. In size and figure it had the appearance of a parallelopiped about one foot in length and half a foot high, the longest side being parallel to the horizon. Its light was so strong that he could see by it part of the neighboring hedge and the water in the river; only in the east corner of it the light was rather faint and the square figure less perfect, as if it was cut off or darkened by the segment of a circle. On examining it a little nearer, he was surprised to find that it changed gradually from a bright red to a yellowish, and then to a pale color in proportion as he drew near; and when he came to the place itself it quite vanished. Upon this, he stepped back and not only saw it again but found that the farther he went from it the stronger and brighter it grew. When he examined the place of this luminous appearance, he could perceive no smell or any other mark of fire." Another gentleman informed M. Beccari that he had seen the same light five or six different times in spring and autumn and that it always appeared of the same shape and in the very same place. One night in particular, he observed it come out of a neighboring field to settle in the usual place.

A very remarkable account of the will o' the wisp is given by Dr. Shaw in his "Travels in the Holy Land." It appeared in the valley of Ephraim and attended him and his company for above an hour. Sometimes it appeared globular or like a candle flame; at others it spread to such a degree as to involve the whole company in a pale inoffensive light; then contracted itself and suddenly disappeared, but in less than a minute it would appear again; sometimes running swiftly along, it would expand itself at certain intervals over more than two or three acres of the adjacent mountains. The atmosphere from the beginning of the evening had been remarkably thick and hazy; and the dew as they felt it on the bridles of their horses was very clammy and noxious.

Similar lights are seen skipping around the riggings of ships at sea under similar weather conditions according to Dr. Shaw. We are told of one which appeared about the bed of a woman in Milan, surrounding it as well as her body entirely. This light fled from the hand which approached it but was at length entirely dispersed by the motion of the air.

Scotland's Elf's candles may be of this nature. These are supposed, upon appearance, to prophesy a death and have been known to set fire to grain stacks. They are a great terror to the people. They will avoid a drawn sword or sharp pointed iron instrument and from that we reason that they are electrical phenomena.

The American Encyclopedia also speaks of Sir Isaac Newton's calling the will o' the wisp vapor shining without heat and maintaining that it is as different from flame as shining rotten wood is different from red hot coals. The author then goes ahead to prove, to his satisfaction, that the whole phenomenon is a result of the "electrical fluid."

After considering the foregoing statements, we are led to the conclusion that the phenomenon has not as yet been satisfactorily explained. The flames seem to set fire to themselves as does phosphated hydrogen or Marsh gas. They seem to be peculiar to certain localities and common at those places. It would seem that the ability of the will o' the wisp to ignite other material with which it comes in contact depends upon its volume. The brightness, warmth, smoke and odor may in large quantities become evident while the same may be wanting in small amounts. On account of the feeble light of the flames as usually observed, the will o' the wisp might be thought of a simply phosphorescent gas if it were not for the experiment of setting fire to the oakum by it.

External Galaxies*

Are There Other Stellar Systems Similar to Our Own?

By Harlow Shapley

IN the present state of astrophysical knowledge, the problem of the existence of external stellar systems similar to our Galaxy reduces almost immediately to the problem of the status of spiral nebulae in the sidereal universe. In treating this question we must deal primarily with the "island-universe" hypothesis of spirals—an interpretation of long standing, which at the present time has many adherents and appears to be growing in general acceptance.[1]

The recent work on star clusters, in so far as it throws some light on the probable extent and structure of the galactic system, justifies a brief reconsideration of the question of external galaxies, and apparently leads to the rejection of the hypothesis that spiral nebulae should be interpreted as separate stellar systems. During the last two or three years a considerable amount of observational material bearing on the problem has come to hand, much of which was either not known or not fully considered by previous writers on the subject.

Four classes of objects, other than spiral and closely associated nebulae, have at times been suggested as possible external galaxies, the first three of which may be dismissed as no longer open to such interpretation: (1) *Large star clouds of the Milky Way:* the affiliation with the galactic region and its characteristic population shows them to be a fundamental part of the galactic system; (2) *The Magellanic Clouds:* the apparent magnitudes of their short-period variable stars determine definitely the order of the distance and size of these detached stellar systems, and prove them to be small in comparison with the galactic system;[2] (3) *Globular clusters:* those so far discovered are recognized now as dependents of the galactic system, although in many respects they are miniatures of the Galaxy and apparently for the most part are external to the regions where most of the galactic stars are found; (4) *Various peculiar nebulae and nebulous stars:* concerning them little is known, but in most cases they are to be classed with the ordinary gaseous nebulae (which are clearly associated with the Milky Way), or with peculiar types of individual stars, or with the faint spirals.

OUTLINE OF EVIDENCE BEARING ON THE "ISLAND UNIVERSE" HYPOTHESIS.

The relation of the spirals to the galactic system is not so easily disposed of as the cases considered above. In support or in partial support of the hypothesis that spirals are external stellar systems arguments based on the following four points may be advanced:

(*a*) Distribution with respect to the galactic plane, assuming obstruction of light in and near the Milky Way.[3]

(*b*) High radial velocities.

(*c*) Certain spectral characteristics.

(*d*) Some evidences of great distance.

Less definite propositions that may be ranged on this side of the question are:

(*e*) Improbability of a single galactic system in the sidereal universe:

(*f*) Physical appearance of a few of the spirals.

(*g*) Resemblance of structure in spirals to hypothetical spiral structure of the Milky Way System.

In the light of recent studies of nebulae and the galactic system the arguments founded on the seven foregoing points do not appear to establish the stellar interpretation; and none of them appears to be particularly troublesome for the hypothesis that the spiral nebulae are not external stellar systems. Many of these arguments in fact, are better interpreted according to this alternative theory that spiral nebulae are truly nebular objects.

Five additional points, which are apparently of much weight, and, taken together, seem decidedly unfavorable to the stellar interpretation of spirals, are as follows:

(*h*) New conception of the dimensions of the galactic system.

(*i*) Measures of internal motion in spiral nebulae.

(*j*) The occurrence of novae in spirals and their magnitudes at maximum.

(*k*) The systematic nature of the radial motions of spirals.

(*l*) The probable dependence of their distribution on galactic position.

Some of the foregoing are not completely independent of each other.[4] Four further points of less weight that may be suggested as opposed to the "island universe" theory are:

(*m*) The possibility of formulating a fairly satisfactory nebular theory of the spirals.

(*n*) Directly measured parallaxes.[5]

(*o*) The data of proper motion relative to mean distances and drifts.

(*p*) The apparent absence of a central nucleus in the galactic system.

REMARKS ON THE PRINCIPAL POINTS FAVORING THE "ISLAND UNIVERSE" HYPOTHESIS.

a and *l*. The well-known avoidance of low galactic latitude by spiral nebulae, and the progressive but irregular concentration to the galactic poles, is most naturally taken as evidence that the distribution of spirals and galactic stars is to a certain extent complementary; therefore, that the spirals are dependent and subordinate factors of the general system. It would be difficult indeed to believe that external and independent stellar "universes" could exhibit such striking relations to our particular stellar system when, in addition to this apparent dependence of distribution of galactic latitude, we also note: first, that the avoidance by spirals (particularly by the brighter ones) is greatest in the direction of the galactic center where the stars, globular clusters, planetary nebulae, etc., are most numerous, and that the avoidance is least in the northern hemisphere where the Milky Way is the thinnest and globular clusters are totally absent; and, second, that the radial velocities observed are not random, but have a definite relation to the galactic system and perhaps even depend on the angular distance from an apical point in or near the Milky Way.[6]

On the other hand, Campbell,[7] Curtis,[8] and others have

*From the *Publications* of the Astronomical Society of the Pacific for October, 1919. Reprinted in the *Journal of the Royal Astronomical Society of Canada*, December, 1919.

[1]Among special discussions of the theory, three should be mentioned: an article by Puiseux, "Spiral Nebulae," *Revue Scientifique*, April 6, 1912; Crommelin's paper "Are the Spiral Nebulae External Galaxies?" *Scientia*, Vol. 21, p. 365, 1917 (reprinted in the *Journal of the Royal Astronomical Society of Canada*, Vol. 12, 33, 1918); and the recent address by Curtis, "Modern Theories of Spiral Nebulae." *Journal of the Washington Academy of Sciences*, Vol. 9, 217, 1919. In all of these the evidence is held to be favorable to the "island universe" theory. The arguments reviewed and extended by Curtis are so fully and clearly expressed that they may be taken as presenting the case for the stellar interpretation of spiral nebulae. The alternative theory that the spirals are not stellar has been maintained little, if at all, in recent years.

[2]*Mt. Wilson Contr.*, No. 151, pp. 20 and 25, 1917; No. 152, p. 2, 1917.

[3]*Cf.* Curtis, *loc. cit.*, p. 225.

[4]For instance, the value of *j* may involve a partial acceptance of *h*.

[5]van Maanen, *Mt Wilson Contr.*, No. 158, 1918.

[6]*Mt. Wilson Contr.*, No. 161, Section VII, 1918. Cf. also reference below to work by Wirtz.

[7]*Science*, *N. S.*, **45**, 531, 1917.

[8]*Loc. cit.*

THE GREAT NEBULA IN ANDROMEDA

It is estimated that it takes eight years for light to travel from one end of this mass to the other. (Photograph taken at Yerkes Observatory.)

proposed that spirals may actually be distributed at random, and that the apparent distribution with respect to the Galaxy can be explained by assuming that obstructing matter encircles the galactic discoid—dark occulting nebulosity analogous to that observed in the peripheral equatorial regions of many spiral nebulae. Patches of dark nebulosity certainly exist in the galactic system, at no great distance from the Sun, and it is quite possible that the apparent avoidance of the lowest latitudes by globular clusters is due to such material.[9] Spirals in the galactic plane beyond the confines of our system would be occulted as readily as globular clusters. In general, the observed distribution could be secured by liberal use of the hypothetical encircling opaque material.

The region avoided by spirals, however, particularly in the southern hemisphere, is many times wider than that avoided by globular clusters. A great area of the southern sky (well out of the Milky Way)[10] is quite transparent both to near and to extremely distant globular clusters, but it is practically devoid of spira-nebulae sufficiently bright to have been observed. We must conclude, it appears, either that the spirals, whether near or distant, do not exist in that direction, or that there is a most remarkable arrangement of obscuring patches that eliminates all spirals but leaves a normal distribution of globular clusters.[11]

b. A few years ago Slipher's discovery that spiral nebulae as a class have extraordinary high radial velocities gave new life to the theory that these objects are distant stellar systems.[12] The average motion of the various types of stars and nebulae has been contrasted many times and the argument advanced that, since all galactic objects have reasonably small velocities, these peculiarly high values should therefore be attributed to separate "universes." During the last few years, however, this supposed isolation of the spirals has been altered. While their average radial velocity exceeds 500 km/sec, it is less than 400 km/sec for one-third of them. A number of galactic stars are now known with space velocities equal to or in excess of 400 km/sec. With the extension of the investigations of proper motion and radial velocity to the fainter magnitudes many high stellar velocities are being found.[13] Many globular clusters,[14] which are certainly subordinate to the galactic system, have radial velocities between 100 and 300 km/sec, and the great Magellanic clouds[15] also appear to have very high velocities of recession. Hence this argument of peculiarity in velocity seems no longer an important one for the "island universe" theory. High speed is not a condition impossible of production by the forces inherent in our galactic system.

c. The integrated and nuclear spectra of spirals are predominantly of a stellar type—usually resembling class G or K. With small dispersion the composite spectrum of a mixed group of stars, such as a globular cluster or a galactic system, would appear much the same. On the other hand bright lines are also found occasionally, and Seares's preliminary work on the distribution of color would indicate a much bluer spectral type for the nebular condensations in a spiral than for the nucleus.[16]

The analogy of the absorption spectrum of spirals with the composite spectrum of a stellar system cannot be carried very far, however, until higher dispersion has been used. We should remember that for many years stars differing so enormously in density, volume, and mass as the giant and dwarf eclipsing binaries of type G were classed together without question. Sidereal bodies in extremely different physical states obviously may give closely comparable spectra on the small dispersion that has been used for spiral nebulae.

d and *f*. With one or two possible exceptions the secondary nuclei in spiral nebulae are so distinctly nebulous that they cannot be considered individual stars. Even in Messier 33, probably the most conspicuously nucleated of the brighter spirals, it is easy on large-scale plates to distinguish between the superposed stellar images and the "softer" nebular condensations. It is possible, however, to see a resemblance of these diffuse nebulous objects to extremely distant stellar clusters,[17] but unless we introduce further unverified assumptions the analogy breaks down when the observed colors are intercompared.

EVIDENCE UNFAVORABLE TO THE "ISLAND UNIVERSE" HYPOTHESIS.

The observational and theoretical evidence against the stellar interpretation of spiral nebulae has already been discussed in various earlier papers on clusters,[18] in the present article space will be taken for only a brief summary of the arguments.

h. Formerly we compared any hypothetical external galaxy with a stellar system supposedly about 10,000 or 20,000 light-years in diameter. Recent studies of the galactic system indicate that its greatest diameter is not less than 300,000 light-years. This newer conception greatly embarrasses the interpretation of spirals as stellar organizations of a size comparable to that of the Galaxy. To be linearly as great as this, though angularly small, demands a distance from the Earth, even for the spirals of largest angular size, that would completely discredit many observational results. For example, if any bright spiral of 10′ greatest apparent, diameter has an actual diameter directly comparable with that of the galactic system, its distance must be greater than a hundred million light-years.

i. Under such circumstances the measures of internal motion by van Maanen, Kostinsky, and Lampland, would need to be summarily rejected. For instance, van Maanen's[19] careful measures of the nebulous points in Messier 101 would indicate rotational velocities greater than the velocity of light if that spiral is held to be even one-fifth as large as our Galaxy now appears to be. Similarly, the systematic drift derived by Wirtz[20] from a study of several hundred spirals, and the average proper motions suggested by the studies of Wirtz and Curtis[21] would indicate appalling velocities in space—quite irreconcilable with the spectroscopically measured velocities of translation and rotation.

j. Moreover, if in real dimensions spiral nebulae were analogous to our galactic system, the absolute magnitude of the novae in spirals would far transcend any luminosity with which we are acquainted, and would be at direct variance with present results on intrinsic stellar brightness. For at the distance computed above the absolute magnitude of a nova of the sixteenths apparent magnitude would be —16, nearly two hundred thousand times as bright as the novae of the galactic system for which van Maanen has determined the absolute luminosities.[22] An upper limit to the intrinsic brightness at-

[9] Shapley, *Proceedings of the National Academy of Sciences*, **5**, 344, 1919.

[10] Between galactic latitudes

[11] A third explanation that spirals, as compared with globular clusters, are very near to the solar system cannot be accepted in the face of other evidences of distance.

[12] That the large line-displacements in the spectra of spiral nebulae should be attributed to motion in the line of sight appears to be assured by a consideration of the following points: (1) The displacements are both positive and negative; (2) the appropriate relation of shift to wave-length is observed; (3) orbital motions in eclipsing binaries occasionally show displacements of the same order of magnitude; (4) in linear velocity the rotation observed spectroscopically in some spirals approaches the velocity in the line of sight.

[13] Adams and Joy, *Mt. Wilson Contr.* No. 163, 1919 *cf.* Wolf's frequent notes on large proper motions in recent volumes on the *Astronomische Nachrichten*.

[14] *Mt. Wilson Contr.*, No. 156, p. 12, 1918.

[15] R. E. Wilson, *Proc. Nat. Acad. Sci.*, **1**, 183, 1915.

[16] *Mt. Wilson Communication*, No. 36, 1916.

[17] *Publications Astr. Soc. Pac.*, **29**, 217, 1917.

[18] *Ibid.*, **30**, 42, 198; *Mt. Wilson Contr.*, No. 157, p. 1, 1918, and No. 161, Sections VII and VIII, 1918.

[19] *Mt. Wilson Contr.*, No. 118, 1916.

[20] *Astronomische Nachrichten*, **203**, 197, 293, 1916; **204**, 23, 1917; **206**, 109, 1918.

[21] *Pub. Ast. Soc. Pac.*, **27**, 217, 1915. In subsequent references Curtis has stated his lack of confidence in the reality of the observed proper motions. *Jour. Wash. Acad. Sci.*, 9, 221, 1919. The average time interval between first and second observations is 13 years and 40 years respectively, in the investigations by Curtis and by Wirtz.

[22] *Cf. Pub. Ast. Soc. Pac.*, **31**, 234, 1919.

tainable by stars is suggested by recent observational and theoretical work, and this limit is much fainter than —16. The study of globular clusters, for example, has yielded sufficient knowledge of the luminosity of more than a million stars to show that not one is within ten magnitudes of this enormous brightness. The luminosity of about 2,000 stars of the solar environs is now known, and probably none is even a ten-thousandth as luminous as absolute magnitude —16. Hence stellar luminosities of this order seem out of the question, and accordingly the close comparability of spirals containing such novae to our Galaxy appears inadmissible.

Let us abandon the comparison with the Galaxy and assume an average distance for the brighter spirals[23] that will give a reasonable maximum absolute magnitude for the novae. Then the measured internal motions also become reasonable and in good agreement with spectroscopically determined rotational velocities; likewise the distances become reconcilable with the data from proper motion.

The simple hypothesis[24] that the novae in spirals represent the running down of ordinary galactic stars by the rapidly moving nebulosity becomes a possibility on this basis of distance, for the brighter spirals are within the edges of the galactic system. Further, it is possible to explain the peculiar distribution of spirals and their systematic recession by supposing them repelled in some manner from the galactic system, which appears to move as a whole through a nebular field of indefinite extent.[25] But the possibility of these hypotheses is of course not proposed as competent evidence against the "island universe" theory.

CONCLUSIONS.

Observation and discussion of the radial velocities, internal motions, and distribution of spiral nebulae, of the real and apparent brightness of novae, of the maximum luminosity of galactic and cluster stars, and finally of the dimensions of our own galactic system, all seem definitely to oppose the "island universe" hypothesis of the spiral nebulae. Data relating to proper motion are also in better harmony with the hypothesis that spiral nebulae are not stellar systems. The evidence now supporting the "island universe" interpretation appears unconvincing, for many of the best arguments formerly proposed on that side of the question have been invalidated or much weakened by recent research. We have, however, no evidence that somewhere in space there are not other galaxies; we can only conclude that the most distant sidereal organizations now recognized—globular clusters, Magellanic clouds, spiral nebulae—cannot successfully maintain their claims to galactic structure and dimensions.

THE USE OF SELENIUM CELLS IN ASTRONOMY.

By Lewis J. Boss.

Selenium is a non-metallic element, occupying the intermediate space between Sulphur and Tellurium. It was discovered in 1817 by Berzelius while he was experimenting with the Falun pyrites, with a view towards producing sulphuric acid from them. Selenium is obtained in three different forms, namely, amorphous, vitreous, and colloidal selenium. There is also another modification of selenium, known as metallic selenium. Of these we need only be concerned with the vitreous and metallic forms.

The metallic form of selenium is produced from the vitreous generally, and is the only modification of the element which is light sensitive. The vitreous selenium is gradually heated until the temperature approaches 100°C. and then begins to pass rapidly into the metallic state, the temperature rising at 217°C.

This metallic selenium conducts electricity and exposure to light increases its conductivity. This effect is most pronounced when selenium is used which has been exposed for a considerable time to a temperature of 210°C., until it has attained a granular crystalline structure.

This final annealing is very essential to making the most sensitive and delicate cells. The selenium must be as pure as possible, as Marc has observed that impure selenium does not crystallize as well in a given time as does pure selenium. As a matter of interest it might be well to note here that in selenium crystals an X-ray analysis shows the selenium atoms to be placed at the corners of triangles in such a manner as to form hexagons. The distance between these atomic centers is 3.69×10^{-8} cm. when measured perpendicular to a regular surface running parallel to the principal axis. These hexagonal plates are fitted one against the other lengthwise, so as to build up an acicular hexagonal crystal. The distance between these as shown by the X-ray spectrum seems to be 3.7×10^{-4} cm., or .37 millionths of a centimeter.

After this crystalline state has been attained by the selenium cell it becomes very sensitive to even the most minute changes and variations in the amount of light allowed to fall upon it. Grupenberg has produced cells which recorded changes of one-hundredth candle power at a distance of a mile. As Marc has calculated the thickness of the selenium layer which is affected by the light action to be about 1/1,500,000 inch thick, it can be readily seen that small variations in light intensity will greatly affect the conductivity of the cell. This change also takes place almost instantly, at least the lapse of time is less than .01 second. There does not seem to be any appreciable difference in the action of the cell whether the light striping it is colored or not, although no one has studied this phase of the subject to any great extent. Personally I have thought that on some cells at least, certain wave-lengths of light, notably λ 680-660 (between the B and C lines of the spectrum) affected them to a greater extent than did other portions of the spectrum.

The field of variable star observations seems to open up a vast field for the use of these cells in that they will detect the smallest changes in light variations where the eye could see no change whatever. Many stars, such as α Orionis whose period has never been determined, offer a field of great interest to observers who may elect to make use of these cells. By means of a suitable indicating device a continuous curve of light variations may be traced throughout the night.

These cells may be used in determining the relative amount of light given off by an eclipsed body and, if calibrated beforehand, could be made to read in direct light units. During lunar total eclipses they might be used to measure the amount of earth-light received by the moon.

Another use to which they might well be put is the comparison of magnitudes and brilliancy of stars. For instance let the cell be arranged to receive the light from star A (let us say); then after noting on the indicating device (galvanometer, etc.) the deflection produced by the light of star A, swing the cell so that it receives the light from star B. If the deflection is the same, then star A and star B are of the same magnitude, but if the readings differ, then the proportion of difference in the readings is the proportion of difference in the magnitude. In this same way the cells might advantageously be used in recording brilliancy changes in Novae.

In view of the great delicacy and sensitivity of these cells it is to be hoped that they will become the subject of more research in the future than they have in the past, and that they may aid in the advancement of man's most sublime science—Astronomy.—Reprinted from *Popular Astronomy*, March, 1920.

[23] Provisionally, let us say, of the order of 20,000 light-years. If novae in spirals attain apparent magnitude 16, certainly bright stars, if present, should be easily photographed, and the failure to resolve the brightest spirals indicates that they are not composed of typical stars. (*Cf.* a suggestion on the origin and constitution of spiral nebulae, *Mt. Wilson Contr.*, No. 161, p. 29, and also the mathematical theory by Jeans, *Monthly Notices* **77**, 186, 1917). At a distance of 20,000 light-years, if there were ordinary stars of absolute magnitudes between 0 and + 5, they would appear of magnitudes 14 to 19, and therefore conspicuous on ordinary photographs. Even if 200,000 light-years distant, the giant stars would be easily resolved on existing photographs.

[24] *Pub. Ast. Soc. Pac.*, **30**, 53, 1919.

[25] *Mt. Wilson Contr.*, No. 161, Sections VII and VIII, 1918.

The Fear of Being Buried Alive

Infallible Signs of Death

IN former times there was a very widespread fear among all classes of society of "burial alive" while in a comatose condition or what was generally known as a trance. Many people took elaborate precautions to prevent such a catastrophe, the fear of which was exaggerated by gruesome tales concerning open coffins wherein the corpses were found to have turned upon one side as if writhing in a vain attempt to escape the hideous death of suffocation, or where if placed in vaults they had gnawed their own fingers to the bone in the piteous effort to keep from starving and with a lingering hope that help might come before it was too late. Some persons went so far as to have coffins with plates of glass set in them, to have graves prepared with air shafts and to have tombs provided with various kinds of signalling apparatus. In 1824, Hufeland had a mausoleum built in Weimar, in which the biers were so arranged as to be connected with an alarm by means of threads fastened to the fingers and toes of the corpses, and a similar building was erected ten years later in Leipzig.

Readers of Edgar Allen Poe will recall that one of his most thrilling and hair raising tales deals with the case of a man who was possessed by such a fear of living interment, and had similar precautionary devices in his own home. Being obliged to take a journey, however, he awoke suddenly one night to the dreadful consciousness that his worst fears had been realized. The dank smell of earth was in his nostrils, he was apparently clad only in a shroud, and when with mounting horror he tried to rise, his head came in contact with a smooth board only a foot or two above him. He felt that the worst had happened! He must have gone into a trance and been hastily buried by the hands of strangers only to wake to face a hideous death by the torture of suffocation or hunger. Happily, returning memory reminded him in a few moments that he had taken passage upon a Potomac river boat the night before and was at present clad in his usual night garments and reposing in a narrow lower bunk upon a vessel which happened to be carrying a load of earth.

Many are the romances based upon the phenomenon of the simulated death of a living person, the tragedy of Romeo and Juliet being perhaps the most famous of all. Such cases abound also in both medieval and ancient European literature, in Eastern collections of tales such as the Arabian Nights, and finally in the folk-lore of many lands—as witness the charming story retold by Grimm of the Seven Dwarfs and their vigil over what seemed the lifeless but incorruptible body of the gentle maiden whom a jealous step-mother had tried to kill with a poisoned comb.

Some animals endeavor to escape their enemies by assuming a rigid and lifeless appearance when threatened, remaining perfectly motionless, even when touched or handled. The opossum is the creature most celebrated for this trick of "playing dead," but various other animals and insects exhibit it.

Strangest of all in this connection is the practice among the devotees of certain Eastern cults, notably in India, of inducing a condition of simulated death by means of fasting, prayer, intensive meditation, and other acts of self-hypnosis. It is even claimed by some of them that while in this state the body may be actually buried in the earth for many days. During this period of what may be called vital quiescence the soul is supposed to be able to leave the body and range at will in other spheres, returning finally enriched by rare spiritual experience. Even Christian annals contain many accounts of supposed journeys to heaven or to hell on the part of the soul while the body lay locked in death-like trance.

Many of the remarkable visions described by persons emerging from such a suspension of physical activities and sensations were undoubtedly related with absolute sincerity, and not infrequently the subsequent conduct of the individual was governed by ideas entering the mind during the supposed absence of the soul from the body. Here we trend upon the still more or less mysterious domain of the "sub-conscious mind." It would in fact be extremely interesting to examine some of these well-authenticated accounts of "unearthly visions" in the light of modern methods of psycho-analysis. But this would lead us too far afield for the purposes of the present paper, whose chief object is the statement of certain infallible signs and tests of death.

Since many people still suffer from such forebodings, though the fear of being buried alive is by no means so widely prevalent as formerly, it is of interest to know what are the true and unmistakable signs of actual death. The subject is interestingly treated in *Kosmos* (Stuttgart) of February 15, 1920. The writer remarks that by the expression "apparent death" we understand a condition in which a person presents the appearance of a corpse though still actually alive. It may be remarked that the better knowledge one has of the actual signs of death the less likely he is to be deceived by a simulated death. Children and wild animals may take a person lying in a faint to be dead, whereas an adult will at once know by his breathing that he is still alive. In the same way every zoologist knows that a fish or a frog can be frozen absolutely stiff and yet be alive, although not giving the slightest outward sign of life; indeed such a frozen animal can actually be cut to pieces without giving any evidence of sensation. At the present time it is extremely rare for a mistake to be made in this matter, because of more general education as well as of the greater skill of physicians than in earlier days. In the great majority of cases death comes with the implacable certainty of natural law. In such fevers as frequently end in death, such as scarlet fever, typhus fever, diphtheria, pneumonia, influenza, peritonitis, and inflammation of the membranes of the brain, or in blood poisoning, the dying person who has previously had a high flush and has been breathing rapidly and has had a rapid heart beat becomes pale and cold while his pulse beat disappears, his breath becomes weak and irregular and he finally gives the "death rattle," which is a characteristic sign of the approach of death. The possibility of any simulation of death is entirely excluded from this typical coming of the end in a demise due to a fever.

In a second class of deaths, which is very frequent, the end comes from the exhaustion of the patient. After weeks or months of illness, the latter, who has wasted away till he is little more than a skeleton, becomes so weak that he is unable to move or to take nourishment. Such deaths occur in chronic tuberculosis, cancer, old age, and the more serious forms of nervous and mental maladies. In this class likewise the possibility of mistake is absent. In a third class after the suffering of "a stroke" there was formerly considerable opportunity for error. For example, a man drops suddenly to the ground while talking, while at work, or while crossing a street and breathes his last in a few minutes. This manner of death befalls persons on the far side of fifty whose blood vessels have become brittle, or children whose heart has been injured by the toxin of diphtheria, or convalescents who have apparently recovered from an attack of the grippe, typhus, etc. In exceptional cases, too, sudden death is due to child-birth or to a surgical operation. In such cases a mistake as to actual death is possible, indeed, but extremely rare. The manner of death of such a person, who suddenly grows pallid, whose respiration falls and whose heart beats irregularly with a fluttering pulse, is so characteristic and typical that anyone who has observed it, even a few times,

can run no risk of making a mistake as to whether the victim is actually dead or not. The conditions which occasion the appearance of death in the living are found in only a small group of maladies. . . . including poisoning with morphine, chloroform, veronal, alcohol, coffee, nicotine; shock due to accident, a heat stroke or sunstroke, suffocation; certain rare forms of fainting, and finally, certain forms, likewise rare, of mental and nervous diseases, e.g. the severest form of hysteria. In all these conditions, and, as already said, exclusively in these and even then only very rarely, the patient sometimes exhibits the appearance of actual death while still living. He lies motionless for hours, he is cold to the touch, and his pulse, respiration, and heart beat may all be so very faint as to be imperceptible under a superficial examination; furthermore, the skin over the entire body may be pallid or blue in color, the eyes fixed and staring and the lips perfectly blue. Then, too, the skin may fail to exhibit the ordinary reflex action even when pierced with a needle. As we have said such a state which is so extremely rare that many experienced physicians may have failed to observe it more than a few times in a lifetime, cannot be distinguished at first glance from genuine death.

It is true that in spite of countless investigations no invariable sign has thus far been discovered by which death can be absolutely predicted within the first few hours after the demise of such a victim. It is possible that a certain sign of death is present, but we know of no such sign which is necessarily present as an invariable indication of death. In 1873 the Marquis d'Ourche offered a prize for the discovery of an absolutely certain sign of death recognizable by laymen. But while there were 100 entries, the prize could be adjudged to no one. Van Hassell's words hold good today: "Death is best recognized by the total impression it makes upon us." The greater the lapse of time after a person's demise the more unmistakable the signs of death become and the surer the diagnosis can be of excluding any mistake.

Those signs of death which sooner or later make their appearance in every corpse and which are more or less evident, so that both physicians and laymen can be quite certain of the fact of death are as follows:

CHARACTERISTIC SIGNS OF DEATH

1. *Rigor.*—The state of rigidity known as the death rigor makes its appearance either immediately or within the first ten hours after death. It consists in a gradual stiffening of the muscles proceeding from the neck downwards. This stiffness gradually disappears in the same manner after the lapse of from ten to 18 hours. This rigor is an absolutely certain sign of death. It can be distinguished from the rigidity due to cold by the fact that only the muscles are stiff, the skin above them remaining slack, whereas where a body is frozen not only the skin is stiff but also those external organs which possess no muscles, such as the ear, the point of the nose, the breast, etc. It is distinguished from the rigidity due to cramp by the fact that the muscles remain in any position which they are forced to assume, whereas when the rigidity of the muscle is due to cramp, the muscle immediately resumes its former position when this is altered.

2. *Death Spots.*—A second trustworthy sign of death is the spots of a bluish red or purplish color which appear upon the skin, being most marked upon the deepest lying portions of the latter, namely, the points where it is in contact with the layer beneath it; these spots are due to the collection of blood in the subcutaneous tissues.

3. *Shrivelling of the eyes.*—The human eye is maintained in a state of considerable pressure by means of an ingenious mechanism and it, therefore, presents a full rounded, smooth, moist, and glistening aspect. When death occurs the blood pressure at once falls and with it the internal pressure of the eye; the eyeball consequently presents a shrivelled appearance.

4. *Opacity of the Cornea.*—Soon after the occurrence of death the cornea of the eye, which during life presents a mirror-like appearance becomes dull and opaque through the alteration in its cells. In consequence of this the bright, warm mirror-like aspect of the living eye is changed into the dull glassy, expressionless gaze of the dead.

5. *Corruption.*—Like all other living organisms the human body is subject to decay when once the vital principle has departed. This decay may be hastened by certain factors such as heat and moisture or may be retarded by others such as cold, dryness, or the use of certain natural or artificial preservatives.

6. *The Green Color of the Abdomen.*—After death the skin of the abdomen assumes a greenish tint caused by the contents of the intestines.

All of these are absolutely infallible signs of death, but all of them may either be absent or so faintly indicated as to be imperceptible in the first few hours after death. Yet it is frequently very important to determine immediately whether a supposed corpse is really dead or merely in a state of stupor, since in many cases a person in the latter condition might be saved if prompt remedial measures are taken, whereas otherwise he would shortly die. It is very valuable, therefore, to know some definite means of determining whether death is actual or apparent without waiting for the appearance of the signs described above. Such information is of peculiar importance and value in cases of public disaster such as eathquakes, fire, flood, shipwreck, explosions, tornadoes, bombardment, etc., where hundreds of persons may be really dead whereas hundreds or even thousands of others may be merely suffering from shock. We quote from the same writer three reliable tests in cases of supposed death.

TESTS FOR THE IMMEDIATE DETERMINATION OF DEATH

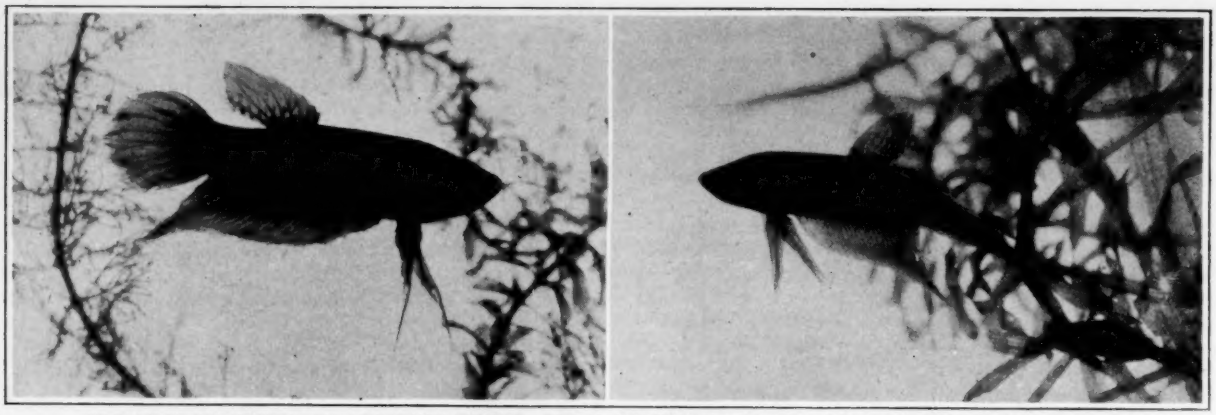
1. *Burning.*—If the skin be slightly burned by a match or bit of hot sealing wax it responds to the irritation when living by the formation of a blister filled with water, and it also has a reddish appearance. When the skin is dead, on the contrary, it forms no blister but separates like a bit of scorched leather, peeling off and showing a whitish color under the torn part.

2. *Finger tying.*—When a living finger has a piece of stout thread tied tightly about it so as to interfere with the circulation it swells through the collection of the blood which cannot follow its appointed course, and when the thread is cut the finger is marked with a white line which gradually turns red. This phenomenon does not occur when the finger of a corpse is tied.

3. *Electricity.*—If a person who is apparently dead though really living is subjected to an electric "shock," the muscles contract in the manner familiar to most people. About three hours after death even the strongest electric current fails to exert any effect upon the muscles.

Since the significant signs of death described above require as a usual thing several hours to make their appearance, the best safeguard against being buried alive is the law forbidding a corpse to be interred immediately after death.

In Berlin recently a nurse was discovered in an apparently lifeless condition and taken to a near-by sanitarium, where the physician declared her to be quite dead and had her body placed in another room. Fifteen hours later the supposed dead woman, however, exhibited signs of life. This case presents an obvious example of the wisdom of the law preventing too prompt interment. A hypothetical case is described as follows: Suppose a man was found lying in the woods seemingly dead from the effects of a large quantity of narcotic poison; suppose, furthermore, that since it was winter time his limbs were frozen stiff, so that the death rigor was apparently present. Suppose, too, that his skin was likewise cracked and altered in color and aspect by the frost so as to present the waxen pallor of a corpse. Suppose again that such a cold, discolored body was examined hastily by insufficient light at night. In such a case even an experienced physician might be deceived. And yet such a supposed corpse might really "come to life" many hours later when the effect of the narcotic from which he was suffering had worn off.



THE MOST BEAUTIFUL OF AQUARIUM FISHES: *BETTA SPLENDENS* (LEFT) AND ITS HANDSOME RED COUSIN *BETTA RUBRA* (RIGHT)

The Humming Bird of the Water

A Fish That Is a Devoted Paterfamilias

AMONG those fishes which are small enough to be suitable for an ordinary glass aquarium, one of the most interesting, as well as one of the handsomest is the *Betta Splendens*. The Betta is a genus of fishes belonging to the group of the *acanthopterygia* in the family of the *labyrinthidae*. All of these fishes have flattened bodies. The ventral fins are triangular and jugular, i.e. under the throat, and are composed of a few rays, the first of which are longer than the others. The pectoral fins are small; the candal fin is large and rounded, consisting of ten rays; the dorsal fin, which is situated nearly in the middle of the back, is short and spineless; the anal fin commences very far forward and ends close to the caudal fin; since the final rays of this fin are longer than the others the lateral line is interrupted. In general the shape and placing of the fin gives a peculiarly graceful appearance to the male fish. There is no swimming bladder.

Several species of the Betta are known including the *b.* trifasciata found in the rivers of the islands of the East Indian Archipelago, Sumatra, Banka, Billiton and characterized by three black bands running from the operculum (or gill cover) to the caudal fin; the fighting *Betta, b. pugnax* of the Malay Peninsula marked by black transverse bands and silvery longitudinal bands, besides two or three bands upon the head; the *bellicose Betta, B. bellicosa;* the red *Betta, b. rubra* and the "splendid" *Betta, b. splendens.* The latter two are dwarfed species not more than 5 or 6 cm. long and are particularly handsome.

All of these species are capable of living comfortably in small household aquariums provided the water in the latter be kept at a temperature of 25 or 26°C., which can easily be done by means of a small lamp. The *Betta Splendens* is especially remarkable for the dazzling beauty of its colors. When perfectly calm both sexes are yellowish brown banded with dark stripes, but when excited the fish undergo a remarkable change in color, form, and general aspect—the fins become bright colored, the back is curved and the gills swell up to such an extent that they extrude from the branchial cavities which contain them and are visible externally. The male exhibits an extraordinary brilliance of metallic tones and reflections; his back is reddish brown with iridescent gleamings while the abdomen and sides vary from red to green, to yellow, and to deep blue according to the way in which the light strikes them. Even the fins share these bright colors, so that the creature has been compared to a humming bird. The female is less vivid in color and her movements are slower and not so supple. These sudden changes of color are readily produced in the male when he catches sight of a rival. It is usual, where two males are kept in the same aquarium to separate them by a pane of glass.

One of the most curious habits of these fish is one which they share with the macropods of the same family, that of placing their eggs in a nest composed of bubbles of foam made by the male. This interesting procedure can be readily observed even in a small aquarium provided the latter be well furnished with plants, such as the *myriophyllae* rooted in sand and a few tufts of *riccia* (a cryptogamic plant similar to the marchenti or green moss); the floating tufts of the latter will serve as a foundation for the nest. If the aquarium is heated to the proper temperature the male will soon begin to take bubbles of air in his mouth and then eject them shooting them upward to a location where the plants are abundant and therefore suitable to retain them. He continues this until he has formed a layer of foam bubbles. These are remarkably persistent resembling glycerine bubbles because of the mucus secreted by the male with which they are mingled. From time to time the fish quits his labors to swim around about his mate, both displaying their most beautiful colors.

As soon as the nest is finished the female begins to lay her eggs, being assisted by the male, who curves himself into an arc of a circle in order to compress the body of his mate. About a dozen eggs are laid at a time, each one millimeter in diameter. These begin to fall slowly toward the bottom but during their descent they are caught by the male and carefully placed in the nest of foam bubbles. The entire deposit lasts two or three hours and from 300 to 500 eggs are produced.

The male now assumes entire charge of the nest, keeping the eggs in position and watching over their development. He is particularly careful to prevent the mother from approaching, probably from well founded fears of her unnatural liking for small fry. The eggs hatch at the end of 24 hours and the male keeps the fry in the nest for a few days until they grow strong enough to escape.

At this time they should be supplied with suitable food, consisting of infusoria, which will pullulate freely if a bit of cabbage stalk is placed upon the water. About 50 of the young fish can be obtained, two or three mm. in length. Their food should now consist of finely chopped earth worms or Daphnia. The most vigorous are ready to breed at the end of four or five months, but the most of them are not sufficiently mature until six or seven months old. They are very prolific, since a couple of weeks after the eggs have been deposited the pair can again be bred.

Parasitism and Symbiosis in Relation to Evolution

A Criticism of Prof. Portier's Theory of Universal Symbiosis

By Prof. Maurice Caullery, of the Sorbonne

Prof. Caullery is a distinguished member of the Faculty of Sciences of the Sorbonne, and is an eminent authority on the science of evolution. Both he and Prof. Portier have done valuable, original research work in biology and we are glad to give our readers the opportunity to compare their contrasting views with respect to the interesting subject of parasitism. The following paper delivered at the Sorbonne, Nov. 5, 1919, is the opening address of a series of lectures entitled "Evolution of Living Organisms."—EDITOR.

I WILL begin my subject by stating briefly the reasons for its choice.

Everyone is cognizant at the present time of the critical phase through which the transformist problem is now passing, a phase indicated by F. Le Dantes in 1909, in the title of one of his books: *The Crisis of Transformism.* This crisis, while a very real one, is undoubtedly merely a crisis of growth. For my part I do not seek to solve this problem, as does Le Dantes and I am ready to acknowledge that the great solutions in which more than one generation of naturalists have had entire faith, namely, Lamarckism and Darwinism, are today quite inadequate, at any rate, in their orthodox forms.

The study of all nature tends to impress upon our minds the conviction that living organisms have undergone a process of evolution and that they have passed through manifold stages before becoming the species whose fossil remains we find and those which are now living under our very eyes. But we do not yet know, it must be acknowledged, the nature of the essential factors in this evolution. All of the experiments hitherto made in the endeavor to furnish experimental proof of the possibility of transformation by natural selection or of the heredity of acquired characters have yielded but meagre results. And in the presence of these results the experimental study of heredity and of variation which have been pursued so actively and so fruitfully since the beginning of the 20th century, lead us provisorily at least, to conclusions which it is difficult to harmonize either with Darwinism or with Lamarckism. It is true that they themselves lead—at least when carried to extremes, to singular paradoxes, as was shown by W. Bateson, in 1914.[1] It is true, also, that what have seemed the best founded hypotheses in the world of science, such as that of universal gravitation or of the principles of electro-magnetism, have also finally encountered objections which have temporarily arrested our opinions with regard to them.

As regards living organisms the conformity of their structure to the conditions in which they live—their *adaptation* in a word, a fact of such general occurrence in nature and so impressively illustrated in the structure of living creatures, can no longer be explained with the beautiful simplicity of Lamarck's theory as being due to the direct action of the surrounding medium modeling the organism by means of its own activities. It seems rather more probable in fact that when the organism undergoes variations it reacts in a manner which is proper to itself and which is derived from its own constitution through the most varied factors which are capable of inciting it to action, and furthermore, that it passes either continuously or discontinuously through a series of forms which progress towards a definite end.

ORTHOGENESIS.

It is this idea which Eimer has tried to express by the word *orthogenesis* and this idea holds a place of prime importance in biology. Thus, one branch of the *Ondulidae*, starting from some ancestor analogous to the *Phaenacodus*, finally produced the horse, the *equidus* and in the same way the elephant type was gradually developed from the *Paleomastodon*. At the present time we have more and more numerous examples of series of this sort. The surrounding medium can have had at most merely an indirect action upon the development of these series . . . accelerating them, perhaps, or retarding them, or possibly exerting upon them a relative effect of elimination.

Under the influence of these data we have seen the reappearance even among those biologists who are rather strong partisans of evolution concepts similar to those which opposed Darwinism upon its origin. Thus D. Rosa has recently published under the title Hologenesis,[2] a theory in which he expresses upon the whole ideas similar to those of Naegeli, and in which he attributes evolution entirely to the interplay of the initial factors in the constitution of the organism.

HOLOGENESIS.

If adaptation is not necessarily a direct and normal effect of the action of the milieu upon the organism, we are led to conclude that it results secondarily from the choice by the latter of a mode of life suited to its previous constitution. This is what Cuénot has called *Pre-Adaptation.* The idea is by no means new; Darwin sought to ascertain how selection could have brought about the tongue of the wood-pecker, which is so marvellously adapted for the search for insects in the bark of trees. But Buffon, one of the forerunners of the transformationists, had already, in describing the behavior of these birds, come to the conclusion that "thus is the instinct of a bird bounded by a miserable and wretched life. He has received from nature organs and instruments appropriate to this destiny, or *rather he derives this destiny from the very organs with which he is born.*" Thus it is in the organ which creates the function instead of vice versa as in the aphorism of Lamarck.

Even if this explanation be fitting in certain cases, as might be suggested by modern experimental researches upon heredity, one would hesitate to assume its general application in view of the mass of adaptation arrangements which exist in nature and in view especially of the graduated series which they present. Would it be possible for a harmony so close and so thoroughly coördinated with the milieu to exist if the latter played no part in its accomplishment? Could a fact of such general occurrence possibly be due to a simple series of coincidences between the mileu on the one hand, and the constitution peculiar to the organism on the other, together with the laws necessary to their transformation? This is aside from a theological or creationist idea.

What still more gives us pause is, that under our very eyes we perceive that the reaction of the individual to the milieu is in a large measure adaptative; the transformation which a plant undergoes in passing from a lowland environment to a mountain environment, or vice versa, furnishes proof of this, but its adaptative modifications do not appear to be hereditary. Perhaps the solution of the difficulty lies in the general indications furnished by paleontology. The different types have not varied in a uniform and permanent fashion. Each one seems to have had its period of variability. During this period we may ask whether the hereditary variations were really independent of the milieu as we observe them to be to-day in organisms which are, perhaps, in a certain phase of stability, or is it true, on the contrary, that the individual adaptative reaction was hereditary.

[1] Presidential address delivered before the British Association for the Advancement of Science (The Australia meeting, 1914).

[2] D. Rosa, Ologenesi (Nuova Teoria dell Evoluzione, etc.) (Hologenesis—New Theory of Evolution, etc.). Florence, 1917.

However this may be the problem of the adaptation remains of prime importance. The phenomenon of parasitism affords an excellent domain in which to study this question, at the same time examining in this connection the question of variation in all its manifold aspects. Furthermore, there is a physiological as well as a morphological problem.

PREDATORYISM AND PARASITISM

From the physiological point of view, in fact, the phenomenon of parasitism presents a series of problems of the greatest possible interest as regards general biology.

To begin with it affords an excellent domain for the study of the reciprocal influence exerted by organisms. All organisms are separate entities and they are mutually engaged in the struggle for existence. The latter is a capital phenomenon, the investigation of which is one of Darwin's greatest titles to fame. But the bond between the parasite and its host is a definite one and the reciprocal action of the two antagonistic parties is definitely limited. But it is necessary here to define parasitism. A parasite is an organism which lives at the immediate expense of another organism, feeding upon the substance of the latter or utilizing the activity of the host's organs in order to obtain the substance of its own body and to accomplish its biological cycle. Except in the case of plants, which assimilate directly the carbon or the nitrogen of the atmosphere and the mineral substances of the earth, all living creatures nourish themselves at the expense of other organisms, and thus might be said to be parasites in a certain sense. But in ordinary conditions the animal kills and devours its prey; it destroys the latter in fact. This sort of life is called *predatoryism* and is properly distinguished from parasitism. The parasite feeds upon the organism at whose expense it lives without destroying it; it exploits the host to a certain degree in a methodical manner by turning aside to its own profit a part of the energy expended by the latter, thus occasioning more or less damage and exerting an action which is often more or less pathogenic in nature, but which is sometimes, on the contrary, perfectly tolerated.

One finds in nature a continuous sliding scale of stages intermediate between predatoryism and parasitism. Sometimes also two living creatures are associated together in a dependent relation, which constitutes to a certain degree an exploitation of one by the other, without there being, however, any direct borrowing by the second organism from the first.

COMMENSALISM

This phenomenon is known as *commensalism*, in other words, as the Latin origin implies, two organisms "eat at the same table." Thus for example, the *Nereilepas fucata*, a polychete, Annelid which is always found at the bottom of the shells of Gastropods (such as the Buccins) inhabited by the Pagures (*Pagurus bernhardus*) profits by the current of water which the Pagure creates in order to draw towards itself the prey upon which it feeds; some of the latter are thus turned aside from the Pagure to the Annelid. But the latter is not a parasite, it is merely a table companion, i.e., a *commensal*. It is difficult, therefore, to draw a definite line between commensalism and parasitism. Certain creatures, such as many of the Infusoria, like the Urceolaria, the Trichodins, and the Vorticellæ live in the homes of other animals of necessity; they are termed *Epizoa;* they are likewise commensals while at the same time borrowing directly from the animal which bears them the power of locomotion as well as very often the condition of aeration and of renewed water supply which are assured by the play of the gills of the host.

One of the characteristics of parasitism is the *fixed nature* and the *necessity* of the relations between the host and the parasite. A true parasite cannot fulfil its vital cycle without the aid of its host and lives at the expense of the latter. These associations are very precise in their nature, however, and are more or less intimate. But it is not always easy to say that in such an association one of the associates suffers at the hands of the other; there are certain very distinct cases in which it can be demonstrated that there is a physiological advantage, in, sometimes a *necessity* for, such an association on both sides. Thus these complexes of two organisms which mutually benefit each other and have a reciprocal intimacy constitute *symbiosis.*

SYMBIOTES.

In a recent book by M. P. Portier, *Les Symbiotes* (Prof. Portiers' views were described and discussed at some length in an article entitled Symbiosis, by May Tevis, which appeared in the *Scientific American Supplement* for November 15th, 1919), the author endeavors to establish the view that symbiosis is not only a phenomenon of general character but one of the fundamental bases of the life of a cellular organism. He regards the cell which is unanimously considered by modern biologists as the fundamental and indivisible organic unit, as being in truth a symbiotic association. In other words his idea is that the cell alone is incapable of existing without containing within it certain bacteria—true symbiotes—whose power of direct assimilation is employed for the benefit of the cell as well as for their own advantage, and M. Portier believes that he can recognize in the organites known to histologists as mitochondria, these symbiotic bacteria or bacteriods.

Autotrophs and Heterotrophs.—According to this author, therefore, living organisms are divided into two classes, namely autotrophs, i.e., bacteria, which are sufficient to themselves and heterotrophs, i.e., organisms having a cellular structure which assimilate their nourishment by the aid of autotrophs.

The capital importance of such a concept is at once evident. Its partisans declare that it will bring about a transformation of the primordial ideas of biology comparable in importance only to the revolution produced by the discoveries of Pasteur. But no matter how clearly expressed and how suggestive a theory may be, it is of value only in case it has been verified by the facts in the case . . . I do not hesitate to declare formally that up to the present time the author has not demonstrated anything convincing as to the justice of his hypothesis, and I believe that objections of fundamental importance may be proved in opposition to it. I make this statement unreservedly, but I am, of course, bound to prove the objections I advance.

OBJECTIONS TO THE THEORY OF UNIVERSAL SYMBIOSIS.

From the physiological point of view the study of parasitism includes a number of other problems. A parasite always lives upon a special sort of host and this specificity, which is always comparatively definite, is sometimes absolutely so. Thus the *Conospora longissima*, a gregarine studied by M. Mensil and myself[3], is constant and abundant in one of the forms of the *Dodecaceria concharum*, which we have designated by B; but it is never found in the A form, and yet this is the same species or, at any rate, a very closely related species of Annelid. Entomophagous (insect eating) Hymenoptera never deposit their eggs except in a denite species of insect. Girard believes, with apparent justice, that the general run of the species of the Epicarid Isopods are parasitic, each upon single species of Crustaceans, and that two similar parasites found upon related species belong to distinct species, even when the precise morphological difference in structure or in form is imperceptible.

The parasite Copepod which M. Mesnil and myself have just been studying[4] under the name of the *Xenocoeloma brumpti* is found only upon a single species of Polycirrus and not upon related species which are found near it. What is the mechanism of this specificity? In these cases, as among

[3] Caullery and Mesnil. Les Formes Epitoques et l'Evolution des Cirratulians (The Epitochal Forms and the Evolution of the Cirratulians) Ann. Univ. Lyon, Vol. XXXVIII, 1898.

[4] *Bull. Biol. de la France et de le Belgique.* Vol. LIII, 1919.

the insects, where the parasite actively penetrates the host, how does the parasite succeed in finding the proper host amid the immensity of nature, and how does it distinguish between related species? Is it through some form of tropism, by some olfactory sensation, for example, as is believed by J. Loeb? In the case of the passive ingestion of spores, as with the gregarine mentioned above, wherein the two forms of the host which live side by side, must certainly ingest the same sporocysts, why does the infection occur only in the B form? And this is closely related to another question, namely: How do the internal parasites, whether in the alimentary canal, in the deep lying organs, or in the colloma manage to exist within their host, maintaining immunity with respect to the humors of the latter's body, or to the phagocytes, whose function it is to digest or destroy the foreign substances or organisms which have made their way into the body? At this point the entire problem of immunity presents itself for our consideration.

And in what manner does the parasite exert an effect upon its host—an effect which is so definite in the case of certain organs. Thus in many instances the parasite produces, from a distance, alterations in the metabolism of its host, thus destroying the genital glands of the latter and producing *parasitic castration*. And after having produced the aforesaid effect, the parasite proceeds by way of good measure to occasion morphological modifications, particularly in the secondary sexual characters. It is a remarkable fact that the transformations thus produced by parasitism sometimes occur in groups such as the Arthropods, in which experimental castration, no matter at how early a stage has never been observed thus far to produce any alteration in these sexual characters. And yet the Sacculina, which more or less tardily infests the Crab, often profoundly modifies the secondary sexual characters of its abdomen and its abdominal claws. These facts, which were first pointed out by A. Girard, have been extended and strikingly illustrated by G. Smith.

In short, the list of important questions in physiology suggested by parasitism could be readily lengthened.

DEGRADATION DUE TO PARASITISM.

But let us return to problems of morphology and their connection with the more general problem of Evolution—as a matter of fact they are by no means independent of physiological problems. The reaction of parastism upon morphology is very striking. There is, in fact, no category of analogous facts in the realm of biology which affords the same breadth of vision. Parasites are distinguished from forms belonging to the same groups by traits so marked that the affinities of these parasites often become unrecognizable. Furthermore, there is an evident parallelism between the transformations which are produced in the various groups.

Parasitic *degradation* is a long established idea. The more profound the nature of the parastism, i.e., the more use the parasite makes of the host's activities to secure his own nutrition, the more the parasite becomes deformed and simplified. Thus, as a general thing the organs of locomotion and those of the senses tend to retrograde and even disappear. In some cases there is even no longer any trace of the original nervous system. The digestive organs become simplified, since the parasite, which absorbs only substances which are already fully elaborated and perfectly assimilable, needs not go to the trouble of making such transformations; there merely occurs a hypertrophy of some organs whose function it is to store up reserve material, such as the hepato-pancreas. The alimentary canal on the other hand, sometimes disappears completely, as among the Cestods, and the animal, immersed in assimilable nourishment, feeds itself by means of simple osmosis through its external tegument; the reproductive organs, in particular, are altered and are generally hypertophied, but in various manners. Sometimes the parasitism manifestly produces hermaphroditism. Sometimes, on the other hand, it exaggerates sexual bi-morphism, making of the female, stuffed with eggs, a giant upon which the dwarfed male lives as a sort of parasite. In one case as well as in the other the number of eggs produced by parasites is enormous—In this enormous production of eggs there is a compensation for the extreme mortality of those embryos and larvae which do not succeed soon enough in finding the indispensable host. This compensation is essentially adaptative and suggests theological illusions. Thus, parasites sometimes consist of little more than enormous egg sacks and the cycle of the parasite, starting from its meeting with the host is summed up in forming the substance of the eggs, laying them, and finally, incubating them until the hatching of the larvae.

There is, therefore, a very great simplification of the various apparatus which take no part in reproduction; there is a *degradation* if one choses so to express it, in comparison with free forms, but this term merely expresses a subjective point of view, and one might be equally justified in saying that parasites exhibit a specialization carried to a greater or less extent and upon the whole a peculiar adaptation which often attains a very great degree of perfection. In their own way these highly adapted forms might be regarded as being very highly organized. I will illustrate these ideas by a few examples and we shall observe, in particular, how a single group often exhibits successive stages of transformation connecting the forms ultimately attained with the normal forms although scarcely any perceptible resemblance between the former and the latter is apparent. Parasites, present together, more than any other category whatever of organisms a collective and striking illustration of adaptation. Nowhere else is the structure so clearly brought out as molded by the kind of life and nowhere else does pre-adaptation seem less probable.

Not only the adult has been thus influenced; the immature stages are no less so, and the requisite conditions in the finding of the host, which often involve a necessary passage by means of a provisory host (and consequently an enormous destruction of individuals in the process of development) are in correlation with the adaptative peculiarities of the larvae and frequently with the phenomenon of embryonic multiplication involving asexual reproduction. The comparison of various groups is, therefore, suggestive in this respect because we can thus observe parallel divergences with respect to normal embryogeny appearing in series which are entirely distinct, as if the action of the environment were effectively shaping in a direct manner the development and structure of the parasites, in a purely Lamarckian sense.

However, the problem is by no means so simple as it may appear. Conditions which are apparently similar sometimes bring about the most opposite results. A very striking example of this is found in the parasite Copepods. They attach themselves to their host after a period of free existence, during which they generally pass through the principal stages of larval development, like the free forms, attaining the stages which are known as syclopoid; they then attach themselves to the host and become deformed and degraded in the usual sense of the words. M. Mesnil and I have just finished the study of the truly astonishing retrogression of the genus which we have called *Xenocoeloma*, which actually succeeds in borrowing from its host, in the literal sense of the word, a portion of the latter's organs! It is impossible to imagine a more complete degradation and a more intensive parasitism. On the other hand let us consider another type of Copepods, the *Monstrillidae*. These peneterate the host as soon as they reach the Nauplius stage. They then lose all their appendages, forming a simple non-differentiated cellular mass which proceeds to develop within the circulatory system of an Annelid,[5] i.e., in conditions of supreme parasitism. One would expect a creature as degraded as possible from this mode of life. But this is by no means the case. From this parasitism, on the contrary, there issues a Copepod magnificently endowed for a free existence and provided with power-

[5] A parasite species has been observed in a mollusc (*Odostomia*). Pelseneer, Bull. Biol. Vol. XLVII, 1913.

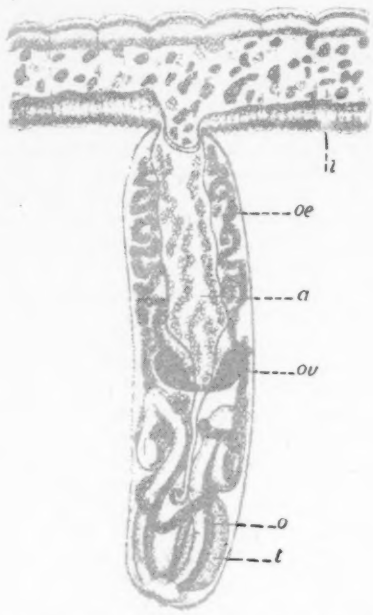
ful appendages for its pelagic life. A single feature of its organism, however, appears paradoxical, and was an enigma before the initial parasitic stages had been studied. The alimentary canal of these adult Monstrillidae is atrophied. We now explain this peculiarity by the fact that the animal accomplished its complete development in the form of a parasite, while its life in the adult stage is merely a brief pause at whose very beginning the sexual products are altogether mature and require only to be disseminated. The animal has no longer any need to assimilate nourishment. In the same manner the innumerable entomophagous insect included principally among the Hymenoptera and Diptera lay their eggs within the bodies of other species, where the eggs develop in the form of parasites producing free and perfect Imagos. In the same way also there is found among the Annelids a series of Eunicians which develop as internal parasites in other Annelids, ending in a free form in the adult state which is in no wise degraded by the parasitism. This shows that the mere fact of parasitism does not necessarily involve simple and uniform transformation.

Thus it is not evident that the striking adaptation of parasites is explicable any more than is the case with free forms by the simple Lamarckian mechanism as was formerly supposed. Here, too, parasites have been able to react according to the successive degrees of a vast orthogenesis. However, it is surely very remarkable to observe that parasitism produces in the most diverse groups parallel modifications which cannot possibly be completely independent of circumstances external to the organisms proper. When a Rhizocephalus crustacean exhibits the asexual modification demonstrated by F. A. Potts[6], is it possible to imagine that this result was an inevitable evolution resulting from the internal factors alone of these organisms independent of external circumstances? Can we refuse to believe that the progressive action of parasitism which, in the general evolution of types can be only a contingency, has been, at least, an external factor of considerable weight, and which has many times produced similar results under similar conditions, but in entirely independent series?

Doubtless free organisms present analogous problems, but parasitism is of peculiar character. The constitution of the fundamental types of the animal kingdom goes back into a practically inaccessible past. But the differentiation of parasites is a secondary evolution subsequent to the first. It is not reasonable to suppose that the parasites, with their intensive anatomical, embryological, and physiological deformations appeared originally in their present form. They are evidently derived from normal forms and nowhere have we stronger evidence of the truth of the theory of evolution . . . This secondary evolution is less remote than the original one, hence the study of parasitic forms is of peculiar interest with reference to the laws of evolution . . .

[6]Carnegie Institution, publication No. 215, 1915.

ANNELID WORM *POLYCIRRUS* HAVING TWO SPECIMENS OF THE *XENOCOELOMA BRUMPTI* ATTACHED TO OPPOSITE SIDES OF THE BODY AS PARASITES



CROSS SECTION OF *XENOCOELOMA BRUMPTI* ATTACHED TO HOST. 14 DIAMETERS

i intestine of *Polycirrus* full of sand and forming slight hernia in the crustacean; *a*, axial cavity of *Xenocoeloma*; *ov*, ovary; *oe*, strings of ripening eggs; *o*, oveduct; *t*, testicle.

. . . We have now arrived at a period in the history of the biological sciences when we are able to form a precise idea of the difficulties presented by their great problems. In the classic period of Darwinism it was generally believed that embryology would reveal all the secrets of morphology. To-day, we no longer hold this view . . . On the other hand, in the domain of physiology which is constituted by factors existing at the present time . . . the progress of all the experimental sciences daily proffers possibilities of new investigations. For example, cellular physiology is today in its prime and is making rapid progress. . . .

The tremendous researches which have been carried on since 1859, under the impulse of Darwin's book, have not enabled us to discover the essential solution of the transformist problem . . . But these researches have given us an incomparably greater knowledge of the forms of animals, of their intimate structure, and of the course of their development. It is thanks to this progress that we now perceive the inadequacy of certain solutions which seemed almost obvious in the years immediately following 1859. And the very difficulties offered by the problem of adaptation have proved that the science of morphology cannot be reduced to a few simple laws. Moreover, it is this progress which has enabled us to formulate the most vitally interesting questions in the realms of physiology . . . An infinite amount remains to be discovered in the domain of morphology and these discoveries may prove decisive for the direction of physiological researches . . . Even to-day we must profoundly admire the information given us by Claude Bernard in his celebrated work, "*Lessons Concerning the Phenomena of the Common Life of Animals and Plants*," with regard to the respective rôles of morphology and physiology . . . In our opinion future researches concerning parasitism show that the last word has by no means been said in morphology and in zoölogy.

THE PERFECT PARASITE.

In the foregoing article a reference is made to a parasite which has undergone such a remarkable degree of degradation as to have even borrowed some of its host's organs. This organism was described recently in an elaborate article by M. Caullery and Mesnil which appeared in the "Bulletin Biologique de la France et de la Belgique," Paris No. 2, 1919. This article is so very interesting and throws so much light on biological problems that we are glad to give a brief résumé of it which we quote from the Revue Scientific, Paris. —THE EDITOR.

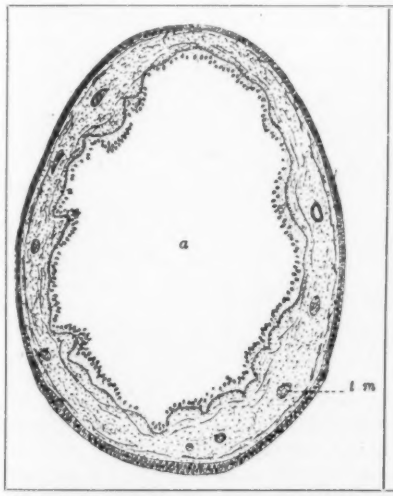
IN the course of their researches concerning the Annelid worms of the Cape of the Hague MM. Caullery and Mesnil found upon a Polychete of the species *Polycirrus arenivorus* a small Copepod Crustacean[1] living as a parasite which at once attracted their attention, not only because of its extreme degree of degradation but also because of its peculiar relation to its host. They named it the *Xenocoeloma Brumpti*, the first word referring to the most remarkable peculiarity of the parasite, namely, that it has no individual alimentary canal. It exhibits an axial cavity which, as a matter of fact, does not really belong to itself, since it communicates with the coelomic cavity (i.e., the body cavity) of the Annelid, being in fact merely a diverticulum or blind pouch of the aforesaid coeloma of the Annelid, and being lined throughout its whole extent by the peritoneal endothelium of the host. However, the degradation due to the creature's state of parasitism by no means ends here.

In aspect the *Xenocoeloma* resembles a small cylindrical rod a few millimeters in length attached to the body of the Annalid. It exhibits no sort of appendage, no special apparatus of attachment, and no prolongation or so-called "root" in the host. It possesses neither mouth nor anus, neither nervous system nor organs of sense, and not even any circulatory apparatus. More surprising still, just as it incorporates within its own body a portion of the coeloma of its host, in the same way it appropriates the latter's teguments, for the external covering of the parasite belongs in reality to the Polycirrus. Paradoxical as this may seem it is amply demonstrated by the numerous drawings and photographs made by MM. Caullery and Mesnil. It is an actual fact that the *Xenocoeloma* has no true tegument, its own having disappeared. The regular and cylindrical epithelium which covers the parasite really belongs to the Annelid; the muscular fibers which are found below and which are striated fibers, which are typical of the crustacean, belong to the parasite. The latter while extending outside the Annelid is still in reality an internal parasite. This shows us to what a remarkable degree the degradation has been carried. Of the original Copepod there remains practically nothing except the genital organs, which are extremely well developed; but other organs are either entirely atrophied or have become unrecognizable. The male animal seems to have completely disappeared while the female has become a hermaphrodite; the male portion of the genital apparatus has the appearance of being a superadded formation, a neoformation. The authors believe, though without distinctly affirming it, that the male genital organs have here been formed at the expense of a purely somatic tissue; if this fact is confirmed by later observation it will prove to be of great interest with respect to embryology. Upon issuing from the egg the larva is a Nauplius of typical aspect but having its various cellular areas heterochronous, i.e. same being retarded as regards the others. The morphological and physiological retrogression of the *Xenocoeloma* under the influence of parasitism recalls the most extreme examples of this phenomenon thus far discovered, such as the Cestods or the Rhizocephala. There is even, in spite of their differences, a certain analogy between these last and the *Xenocoeloma*. As the authors observe nutrition is accomplished in both cases at the expense of the host by a diffused absorption apparatus and beginning with products which are completely assimilated. In the case of the Sacculina the parasite accomplishes this object by penetrating with its roots all portions of its host's organism; but in the case of the Xenocoeloma it is the host itself within whose body cavity the entire body of the parasite is immersed.

[1]The Copepod Crustaceans include the ordinary water flea.

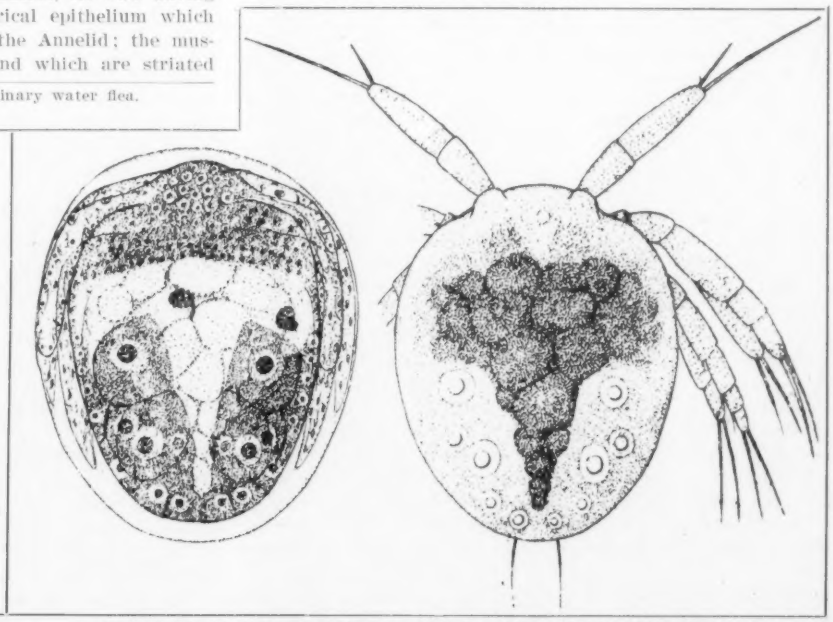
THE EFFECT OF PRESSURE UPON THE EYEBALL.

THE curious fact has been noted by a number of observers, including among others, the French investigators, MM. Achard and L. Binet, that ocular compression has as a result curious reflexes in other parts of the body, both in man and in animals (the rabbit and the dog). Such compression causes a marked modification in the functioning of the heart and other reflexes due to this cause affect the respiratory action, the blood vessels, and even the muscles.



TRANSVERSE SECTION OF YOUNG *XENOCOELOMA*. 155 DIAMETERS

a, axial cavity lined by peritoneal endothelium of the annelid; *tm*, *empty* maturation tubes of oöcytes immersed in a parenchyma intersected by muscles.



NAUPLIUS READY TO HATCH (LEFT) AND AFTER HATCHING (RIGHT). ENLARGEMENT 540 DIAMETERS

Observe the enormous lateral cells of the posterior region and the two nuclei of the vitelline mass. (Note that the term "Nauplius" is applied to a crustacean larva having three pairs of locomotive organs, a median eye and little or no segmentation of the body.)

GATHERING COCOANUTS IN THE PHILIPPINES

EXTRACTING SAP FROM THE COCOANUT PALM

Cutting the Cocoanut Cake

The Growth of the Tree and the Preparation of Its Products

By May Tevis

WHEN a commercial enterprise pays big dividends the process of dividing the shares is known in common parlance as "cutting a melon." If the commercial importance of the cocoanut trade continues to expand as it has done during the last few years, cocoanut groves will undoubtedly become so valuable that the sharing of profits from them may come to be known as "cutting the cocoanut cake." One of the greatest industrial geniuses of modern times, the famous multi-millionaire soap boiler, Sir William Lever, now Lord Leverhulme, of Port Sunlight fame, declared in the foreword of a book published shortly prior to the war, "I know of no field of tropical agriculture that is so promising at the present moment as cocoanut planting and *I do not think in the whole world there is a promise of so lucrative an investment of time and money as in this industry.*"

The very title of the book in which these enthusiastic words are found, "Cocoanuts: The Consols of the East," (1913) indicates his belief that such property is as valuable a security as British Government Bonds. Such an investment, in fact, might be said to be even better than government bonds since its value steadily increases for a number of years. The reader, who has thought of the cocoanut chiefly as an agreeable ingredient of cakes and confections will be curious to know the basis of so sweeping a statement—a statement which is agreed with moreover by various other authorities upon the subject. The answer is to be found in the enormous and steadily increasing value of cocoanut products.

PRODUCTS OF THE COCOANUT TREE: COCOS NUCIFERA

The chief of these products are copra, coir, cocoanut butter and toddy. But these are not all, since it has been computed that the cocoanut yields no less than 84 different products of value.

The cocoanut tree may be regarded, indeed, as one of man's most valuuable servitors, so that there is little wonder that some native tribes worship it as a symbol of divinity. This magic tree furnishes its happy owner with not only food, drink, and wine, but with oil, vinegar, light, timber for the making of houses and furniture, and fiber for the making of textiles, cordage and fish nets.

Before describing the preparation of the four chief commercial products we may cast a glance at some of the minor products. The nut itself is largely used by confectioners, restaurateurs, vegetarian specialists and others, not only in the popular dessicated form, but in numerous other ways.

The copra residue, after the oil has been expressed, yields a splendid food cake for cattle, sheep and poultry, being exceptionally rich in oil, albuminoids and digestible carbo-hydrates.

The shell serves many ornamental and domestic purposes, being used in the making of drinking bowls, beads, dagger handles, hookahs, ladles, water dippers, combs, fish hooks, spoons, rubber tapping cups, gourds, linoleum and other articels too numerous to mention. It also makes a superior charcoal, used in filling gas masks.

The dust of coir fiber is worked up to make felt for use under carpets.

The stem is utilized for furniture, fancy articles, sailing boats, rafters, laths, etc. Hollowed-out stems are used as channels, gutters, etc., and are largely employed in building operations among the natives. The wood is also susceptible of

a high polish and, under the name of porcupine wood, is imported into this country for use in cabinet making.

The bark yields a strong, cohesive gum.

The husk makes valuable manure, rich in potash and phospheric acid.

The leaves furnish excellent roofing material, mats, baskets, brooms, fodder for cattle, and manure. When burnt they produce an ash so rich in potash that it proves a good substitute for soap.

The nut, when young, supplies a delicious cooling drink and an attractive desert. It is also an ingredient for curry.

The green husk makes a toothsome preserve.

The young leaves are used for making a piquant pickle.

The early shoots of the seedling form a delicious vegetable.

Copra.—Copra is the trade-name given to the kernel of the cocoanut after it has been dried, when it is quite white, possesses a pleasant smell, and breaks with a sharp brittle fracture. The ideal article has been described as "that which yields a clear, white oil, free from fatty acid, pleasant and smooth to the taste, and having no pungent and acrid smell. The producers on the Malabar Coast, who have been established there for many years, have by dint of much devotion and energy succeeded in putting on the market an almost perfect product, even when prepared in bulk, almost wholly free from deleterious substances, which therefore rightly commands the keenest competition and the highest prices."

The process of drying the cocoanut is effected by one of four methods, which are: (1) In the sun; (2) in kilns; (3) in hot air chambers; (4) in rotary hot air appliances. The nuts are first husked and split open with a cutlass, and the milk is then poured out. The broken cocoanut is then divided into several pieces, from each of which the white kernel is extracted with a sharp knife, the pieces being spread out in trays, and, if the first process be adopted, exposed to the sun for a period of five to ten days, according to circumstances. In the old days the natives simply broke their cocoanuts in two and laid the halves on the ground on barbecues, or on drying racks and hurdles, with the kernel exposed to the sun. But trays are now in general use, and these are frequently attached to shelter houses, into which they can be transferred at night, or when rain threatens.

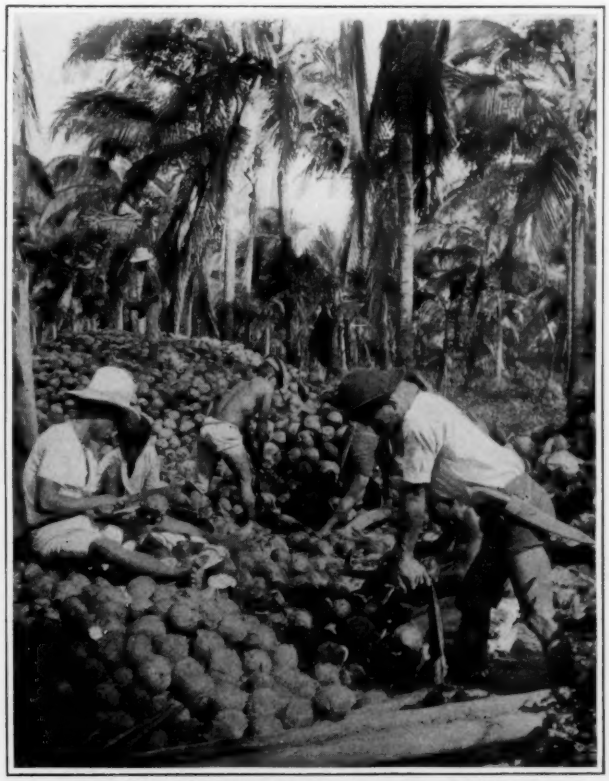
Although sun-drying produces a good-looking copra, it usually leaves behind it from 6 to 20 per cent of moisture, which influences the development of mould, a defect that seriously diminishes the market price of the product. This mould is ascribed by some authorities to the fact that fermentation can take place during the slow process of sun-drying. Experiments conducted by experts have established the fact that to obtain a copra free from any tendency to develop mould the moisture retained must not exceed 5 per cent. The impossibility of being able to depend upon a continuance of brilliant sunshine throughout the entire period of preparation renders sun-drying an uncertain, expensive, time-wasting process as compared with more scientific and up-to-date methods.

Generally speaking, in the Dutch East Indies the nut is gathered green and immediately cut into quarters by the natives by means of a sharp knife. Then it is exposed to the sun, on the beach or some other place, and it dries naturally, while retaining its white color. When dried the copra is placed in gunny bags for shipment. The work of drying, collecting and baling has long been almost entirely in the hands of the Japanese, who have demonstrated their superiority in this work.

At the drying stage women and children are employed to turn the copra and keep it well exposed to the sun. Living being cheap, consisting as it does mainly of fish and rice, the wages paid to these workers are extremely low.

Cocoanut Oil or Butter.—While copra can be used as a food and is so used by the natives, its great industrial value to the world is as a source of oil. For many years there has been a steady shrinkage throughout the world in the production of animal fats, whereas there has been a steady increase in population. This decrease in the available percentage of animal fats per capita was very marked even in the first 14 years of the present century. The Great War enormously increased this shortage of fats in three ways—the decrease

RAFTS OF COCOANUTS ON A PHILIPPINE RIVER



STRIPPING OFF THE HUSKS OF THE COCOANUTS

in production of oil bearing fruits and seeds, the increased consumption required in the feeding of armies since fats are an invaluable source of heat and nourishment for the human body, and finally, the enormous waste of fats involved in the manufacture of glycerine, the source of nitro-glycerine and other high explosives. At the present time the world is suffering from a fat famine, to which the present price of table butter bears melancholy witness even in the United States; but in the last few years cocoanut oil has come to be used upon a colossal scale in the manufacture of nut butter and other cooking fats, of soap, candles, cosmetics, glycerine, etc., as well as for lubricating and illuminating purposes. It is sometimes used also as a substitute for cod liver oil, being far more palatable than the latter, while likewise highly nutritious.

In former times cocoanut oil was extracted by very primitive native methods from the copra. Oil extraction is now, however, a factory rather than a plantation process. It involves two essential phases: First, the maceration of the copra, and second, the separation of the oil. The maceration is very perfect, consisting of grating or scraping and then of very thorough grinding. The oil is extracted by means of large and powerful hydraulic presses. In some cases there is first a cold pressure to produce oil of the best quantity, and afterward a pressure after treatment with hot water or steam; or the pulp may be squeezed both times after a preliminary heating to facilitate the removal of the oil. Oil expressed cold is as a rule of better quality, and oil destined for use as food is usually secured in this manner. After the oil is expressed it is permitted to separate by standing. The upper layers, usually cold enough to be sold in consistency, are then removed, and the residue is again treated to secure the remaining oil of poorer quality. The best mills in Europe sometimes succeed in extracting more than 70 per cent of oil from the copra used. This demands not merely very complete extraction but also that the copra used should have contained very little water. With most of the copra marketed it is impossible by the most perfect treatment to secure more than 65 to 67 per cent of oil.

Where the oil is required in a colorless condition, as for toilet and perfumery purposes, the Malabar system is to plunge the kernel into boiling water for a few minutes; it is then grated, subjected to pressure, and the pulp thus obtained reboiled until the oil rises to the surface.

Some Malabar experts pride themselves on their ability to produce oil so white that it is almost impossible to distinguish it from water when the two are placed in phials side by side. In the ordinary temperature of tropical countries the oil maintains a liquid form, but in lower temperatures, such as those common in this country and in Europe, it assumes a white butter-like solidity. Under conditions of extreme cold it can be separated into two distinct constituent elements, the more liquid of which is known as olein and the more cold as cocosin, or cocostearin, which is a somehat complex constituent containing fatty acids. When the oil is fress the flavor and odor are agreeable, and in that condition it is largely used in the East for food purposes and cooking. But there it rapidly becomes rancid, and when in that state is used for illuminating, soap-making, and other industrial purposes. Throughout the East kerosene is slowly superseding cocoanut oil as an illuminant, especially since mineral oil was discovered in Burmah and other Eastern regions.

The advantages claimed for nut butter prepared from cocoanut butter are its highly nutritious quality and the number of calories furnished the body, its freedom from pathogenic germs, the readiness of its digestion and the completeness of its assimilation by the body, besides, of course, the fact that it is much cheaper than cow's butter.

Oil Cake.—After the oil has been expressed from the copra, there is a residue which forms a valuable cattle food, or if not rquired for that purpose, makes an efficient fertilizer. In the East this residue is known as poonac, and the cake made from it possesses four valuable qualities, which are: First, the milk produced by poonac-fed cattle is of a better quality; secondly, the quantity is usually increased; thirdly, the resultant cream is firmer; and fourthly, the butter proportion is larger, and the color and flavor are improved.

Coir.—Coir is the commercial name of the fiber prepared from the husk of the cocoanut. The word is Malay or Indian in origin, but has been adopted into European languages. In countries where cocoanut culture is very old, the use of this fiber likewise dates further back than our knowledge reaches. In Polynesia and extending as far west as the Marianne and Caroline Islands, this is the main material used for cordage. It was in use as far west as Ceylon before the discovery of this part of the world by Europeans. In these parts of the world it served not merely for rope, and for string to make fish nets, or to tie the parts of houses together, but to calk boats, and in various other ways. For calking boats it is better than most other durable fibers because it will swell more when put into water, and will therefore make a tighter plug.

The chief peculiarity of coir rope is its elasticity. The cocoanut fiber will stretch fully 25 per cent without breaking. The amount which ropes made of it will stretch depends upon the method of manufacture, but in all cases they will stretch more than ropes made of any other of the commercial fibers. This makes coir rope especially desirable where it is subject to jerks. As used for fish nets, and in other ways which demand exposure to water, coir has the advantage that it is more durable than most other fibers; that is, it is less subject to decay.

The breaking strength of coir is 39 kg. when fresh and 24 kg. after having been immersed in water for 116 days, a length of time which causes the entire decay of both English and Indian hemp and of the American agave. The individual cells of coir are shorter than any other of the most important commercial fibers, including those of the ramie, of hemp, of flax, of abaca, of the American agave and of jute. Thus, the average length of the ramie fiber is 150 mm. whereas that of the coir is only 0.7 mm.

The strands which are extracted from the husks of the cocoanut and which are referred to in common speech as the fibers are 30 cm. more or less in length, depending of course on the size of the nut from which they are taken. The diameter is about 0.3 mm. In cross section, they are roundish or somewhat heart-shaped, the concavity or groove along one side being the place where the vessels were located. The strands are harsh and more or less dark in color according to the nuts from which they were secured and the method by which the fiber was extracted. The fiber is strongly lignified, and to this is due its color and harshness, and its relative brittleness as compared with pure cellulose fibers.

From what has been said as to the qualities of the coir, it follows that for ropes it is to be recommended where elasticity or resistance to decay are especially desired; but for general use it is an inferior cordage material because the brittleness of the strand makes it wear out more rapidly than many other kinds of rope, and because it is weaker than the best rope material. As a textile fiber it is of very little general value because of its coarseness, harshness, brittleness and color. The color can be removed, at least in very large part by chemical bleaching, but this treatment leaves it too weak for practical use. On the other hand, the qualities of harshness and stiffness and dark color all make it an especially good material for doormats and hallmats and for various kinds of brushes. It is for these uses that the coir has its chief market value. This combination of stiffness and elasticity also gives it a certain value as a stuffing fiber, and the poorer qualities of coir are marketed, under the name of mattress fiber, for such use.

It is also made to combine with wool in the manufacture of carpets and rugs of great durability and richness of effect, and to make brushes and brooms for household and stable purposes, matting for sheepfolds, pheasantries and

poultry yards; string for nurserymen and others for tying up trees and various garden purposes; nosebags for horses, mats and bags for seed crushers, oil presses, and candle manufacture. The refuse o fthe husks is used by horticulturists for many purposes.

A vast commerce is also conducted in the manufacture of coir cables, which are not only strong, elastic and buoyant, but are improved and strengthened by immersion in sea water, although fresh water is said to rot them. These cables are somewhat rough to handle, and not quite so neat looking as those made of hemp, but their greater elasticity renders them superior for many purposes.

Toddy.—In the East Indies palm sap used as a beverage is known as toddy. In the case of the cocoanut the sap is obtained from the unopened flower cluster. This is gradually bent downward so that when cut the sap will drip freely from the cut end. The tip of the cluster is then removed with a sharp knife, enough being cut off to include the ends of the younger branches of the panicle. The toddy collector carries a vessel usually of bamboo into which he pours the sap which has flowed from each cluster, leaving in its old place the vessel into which the sap has dropped. Each time the tree is visited another thin slice is removed from the cut surface and the thinner the slice the longer the toddy will continue to flow. If a slice is removed three times a day instead of only at morning and at night, a greater flow can be obtained for the 24 hours. The toddy is used either as a fresh beverage, or for the production of liquor, as well as for making sugar and vinegar, and as a source of yeast.

Arrack.—The strong liquor distilled from the sap of the cocoanut and other palms is known as arrack.

Sugar.—Cocoanut toddy has long been used as a source of sugar through out the Far East. The business, however, is everywhere a purely local one. The sugar content of the sap as it flows from the tree is high enough for the sap to be figured as a cheap source of cane sugar, but the fermentation is so rapid that the sugar which can be made from it is decidedly high-priced. For the manufacture of sugar, it is necessary to inhibit the fermentation of the sap as completely as possible. The commonest way of doing this in Malaya and Ceylon is to put into the vessels which collect the sap a little of some finely powdered bark which is rich in tannin. The sugar which is produced in this way is called "jaggery." From good sap, 1/12 the weight of jaggery can be produced.

THE GROWTH OF THE TREE.

As our pictures show, the cocoanut is a tall, handsome, and picturesque palm. While it is found in many parts of the tropics where it is able to obtain enough water, it yields the best results between the latitude 70°N and 12°S, which are outside the hurricane zone. Authorities differ as to whether its original home is in the islands of the Pacific Ocean or whether it is, like all other species of the genus to which it belongs, a native of tropical America. The nut thrives best where the mean temperature is from 75° to 85°F. and the mean annual rainfall is not below fifty inches. It derives special benefit by growing on the sea shore, as the palms require constant and adequate moisture, and soil that does not become sour and waterlogged, for their highest development. Mountainous districts are not favorable to the cocoanut, nor are localities with a torrid and dry temperature. Most experts agree that the best and most prolific estates are located near the sea, upon fairly level land, where rivers and torrents have brought down deposits of rich, friable loam. "The nearer the coast the better the nut" is the general dictum, although trees grow with fair success up to an altitude of 2,000 feet provided that the temperature requirements are fulfilled. But the cocoanut palm does not flourish on steep slopes nor in positions that are overshadowed and sheltered, and it cannot tolerate the presence of stagnant water in the neighborhood of its roots. Ample sunlight, a sufficiency of moisture and large quantities of salt in the soil constitute its essential requirements, and that is why it prospers on sea beaches or in places near the sea.

Obviously, soils vary according to region and location, but the best is an alluvial loam. Given this advantage the trees reach a state of great luxuriance. Light, deep, sandy loams overlying coral or some other porous substratum are also suitable, but the plant depends to a considerable extent on the fertility of the soil and requires a liberal supply of humus—i.e., decayed vegetable matter. Cocoanuts do not prosper on pure sand alone, unless it be repeatedly fortified by quantities of manure and humus. Heavy clay soils and all those with an an impermeable substratum which are likely to hold stagnant water, as well as all shallow soils, should be carefully avoided.

When the trees come into bearing the ripe nuts are usually gathered every two months by means of a knife attached to a pole. When the trees have reached a height of more than fifty feet however "cocoanut collectors" are employed. These pickers climb the trees until they reach the top where they are so near to the fruit that they can readily tell which is ripe and which is not. At the same time they are able to search for and destroy the beetles which attack the cocoanut tree. Very high trees can be climbed only when the weather is fairly dry since in the wet weather the trunks are too slippery. The coir substance, which clings to the stem must on no account be interfered with, since it assists in retaining the moisture around the bud.

It is better to let the nuts remain unhusked for two or three weeks after gathering, since this always insures a larger yield. It is estimated that 40 nuts per year can be counted on from each tree, though some give a much larger yield. The first transport of the cocoanut from the estate is frequently accomplished by binding them together into a sort of raft and floating them down canals to the sea.

COMMERCIAL IMPORTANCE OF COCOANUT PRODUCTS.

Not only has the shortage of fats become menacing to health and life in America thus ensuring, as we have said, a wide market in the Occident for cocoanut oil, but it is expected that a constantly expanding market for this product will be found among the 600,000,000 of the population in China. In "All About Cocoanuts," the interesting volume by Belfort and Hoyer a somewhat curious reason for this is given, to the effect that at the outbreak of the Russo-Japanese war oil producers in Europe and America made a sudden raid upon soya bean oil as a substitute for more expensive edible oils. This forced the Chinese to buy cocoanut oil as a substitute. But although soya oil receded in price the Chinese consumer has meantime become accustomed to the cocoanut oil and even prefers it.

The following figures represent the imports of cocoanut oil and copra for the fiscal years of August, 1913, to July, 1914, as compared with 1918-1919:

Cocoanut oil:

August, 1913, to July, 1914.....	74,067,372
August, 1918, to July, 1919.....	345,737,913

Copra imports:

August, 1913, to July, 1914.....	100,853,374
August, 1918, to July, 1919.....	296,599,419

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The author is specially indebted in the preparation of the present article to the two books which come first upon the present list:

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Chemical and Physical Properties of Dye-Stuffs*

Acid and Basic Dyes in Gelatin Solutions

By J. Traube and F. Koehler

[*The original article is both too long and somewhat too technical to be reproduced here in its entirety. It is of such great value, however, especially in view of the remarkable expansion of our dyeing industry that we are glad to publish an abstract of such portions of it as are of general interest.*—THE EDITOR.]

IN a previous number of this journal (1915, II, 42) we published an account of our researches concerning a large number of salts, acids, bases, narcotics, etc., with respect to the degree of rapidity with which a gelatine jelly at a given temperature (about 26°C.) passes over into the hydrosol conditions upon the addition of one of the said substances, as also the rapidity of formation of the gelatine jelly from the hydrosol condition in the presence of the acid substance. We found ourselves in agreement with the previous researches of Pauli, Schibig and others, to the effect that the dissolving of gelatine corresponds to a process of swelling while the formation of jelly corresponds to a process of shrinking. We found further that the laws determined for gelatine are applicable to other colloids such as albumen. This suggested that it would be of especial interest to extend these researches to the domain of dyestuffs. . . .

We are indebted to the "Badischen anilin-und Sodafabrik" for the following dyes, rhodamin B extra, night blue, rose aniline, eosin B extra, erythrosin G, pure red B conc., phloxin P, Bengal rose A.T., anthraquinon-green G.X.N., wool-violet S, methyl-green, crystal-violet, methylene-green BX, Toluidin-blue, methylene-blue, Nile-blue A conc., malachite-green BX, indigo-carmine.

From L. Casella & Company we received new-blue R, cyanol-pure-green G, water-blue, acid-green extra, tannin-heliotrope, cyanol-green 6G, formyl-violet SB, brilliant walk-blue, indazin N, acid-violet BS, naphtindon BB, isamine-blue 6B, tetracyanol SF, diamond phosphine R, cyanol FF, trypan-red and patent-blue V.

From C. A. F. Kahlbaum we obtained safranin G extra, Bismarck-brown extra, neutral-red extra, quinolin-yellow, martius-yellow, picrin-acid, gentian-violet BR, heliotrope BB, pure brown G, Congo-red, orange I, napthol-green B, azo-blue, azo-ruby S, Bordeaux R, naphtol-yellow S, thionin-blue, methyl-orange, brilliant-Congo G, light-green S, diamine-blue 3B, guinea-green B, Victoria-blue B, and rhodamin B.

Finally, we obtained from still other sources benzo-purpurin B and alizarin-saphiol, chrysaniline S, and chrysoidin S.

It is only too well known that in the case of many of these dyestuffs one must take into account certain impurities and adulterations.

THE RAPIDITY OF SOLUTION AND OF FORMATION OF A GELATINE JELLY.

We made use here of the same simple method employed in our previous work: 6 ccm. of a 0.1 per cent dyestuff solution was mixed with 4 ccm. of 6 per cent perfectly pure and neutrally reacting Nelson's gelatine which had shortly before been heated to about 50°C., regeant glasses of equal width being employed. After a certain lapse of time the glasses containing the congealed gelatine were placed in a thermostat (usually at 26°C.) and the melting of the gelatine was determined by means of small balls made of solid glass (these being better than beads). In the control solutions water was added in place of the dyestuff solution. The direct error of observation could not have been greater as a general thing than from one-half minute to one minute; however, in jellies of almost complete opacity, which were illuminated with an arc light, the error may be somewhat greater.

Since it was observed that the time required for solution of the jelly apart from the substance added depended primarily upon the length of time it took the jelly to form, the solution-periods for pure gelatine and for various dye-stuff gelatines were first determined. . . . The jellies were kept in an ice box. [*Table omitted.*] The first observation made was that the well-known continuous alteration (lasting for weeks) of a gelatine jelly, which can be perceived by the lessening of the vapor pressure, etc., corresponding to a shrinking process . . . and since such a hysteresis is not confined to gelatine alone this gradual process of shrinking is of much significance with respect to manifold biological and technical questions concerning the most various colloids, problems for example concerning dyeing and tanning processes, the period of incubation, etc.

It was further observed that the highly colloidal basic dye-stuff, night blue (which contains dextrin) has a strong shrinking effect while the weakly basic rhodamin B behaves not much unlike water. Among the acid dyestuffs anthraquinon, like benzo-purpurin, has a strongly swelling effect while Bengal rose which like night blue does not permeate plant tissues—after a lapse of three days—has a shrinking effect. . . .

We next allowed the gelatine solutions which had served for the experiments to congeal once more and after a lapse of twenty-four hours placed them again in the thermostat at 26°C. and noted the time required for solution. [*Table omitted.*]

Later, the gelatines were again placed in the thermostat (after a lapse of another twenty-four hours) after previously being congealed in a freezing mixture at —10°C. and the solution time again noted. [*Table omitted.*]

It was found that after several days dye-stuff jellies, such as the gelatines of anthraquinon benzo-purpurin in which the dye-stuffs have a swelling action gradually undergo liquefaction starting from the surface even at ordinary temperatures or in the ice box, while in the case of dye-stuffs which exert a shrinking action, such as Bengal rose, night blue, etc., a similar liquefaction was not observed even after eight days. This phenomenon which was discovered to be quite general among the various dyestuff jellies examined is partly, but not entirely, dependent upon the collecting of bacteria and bacterial toxins.

It must be noted that the above mentioned dye-stuff-gelatine hydrosols, also can be refrigerated at —100°C. into solid carbon dioxide plus ether. The subsequent melting at 26°C. revealed, however, only very slight differences in the solution times compared to hydrosols which had been congealed at 0°C. . . .

Since the differences in the degree of shrinking and swelling of the dye-stuff jellies increase in proportion with the duration of the time during which the jelly is kept before the solution test, the following experiments were all carried out in such a manner that the jelly had previously been kept seventy-two hours in the ice box. The degree of concentration of the jellies was the same as above and the temperature in the thermostat was 26°C. to 26.5°C. Several days later (four to eight days) the experiment was repeated at a temperature of about 28°C. [*Here follow the series of figures obtained which are omitted.*]

The most noteworthy result of our experiments as shown in the tables is the demonstration that basic dyestuffs exert a shrinking action while acid dye-stuffs, on the other hand, exert chiefly a swelling effect, though a lesser portion of them

*Translated for the *Scientific American Monthly* from the *Internationale Zeitschrift fuer Physikalisch-Chemische Biologie* (Berlin).

also have a shrinking effect. The acid dye-stuffs which exert a shrinking action (Bengal rose, erythrosin, phloxin, pure red, pure brown, azo blue, etc.) belong as we shall see to the impermeable or slightly permeable dye-stuffs. It is these whose jellies do not deliquesce in the air.

It is a well-known fact that the non-crystallized basic dye-stuffs sometimes contain admixtures of dextrin, etc., while the acid dye-stuffs contain sodium sulphate, sodium bisulphate, etc. Since, however, only 0.06 per cent of the dye-stuff was contained in the jelly, the small quantities of such salts present are practically without influence upon the swelling; other experiments proved that even 0.5 per cent of dextrin had no influence upon the swelling. . . .

In the shrinking and swelling action exerted by colloids on the part of dye-stuffs we believe we have discovered a new factor which sheds light upon the most various phenomena not only in the technology of dyeing and tanning but in histology and possibly in photography, since what has here been proved true with regard to gelatine is likewise applicable to numerous other colloids, albumen, the fibers of plants and animals, etc., as shown by our experiments.

The greater the shrinking effect exerted by a dye-stuff the less necessary is it in general to assist the fixation by the employment of a special mordant. [*The accompanying tables are here omitted.*]

As shown by the tables basic dye-stuff may be expected as a usual thing to accelerate the formation of the jelly while most acid dye-stuffs retard the formation.

THE CAPACITY FOR DIFFUSION IN JELLIES AND ITS RAPIDITY; ALSO SWELLING AND SHRINKING IN RELATION TO CELL PERMEABILITY.

In a comprehensive study concerning the absorption of colloids by the vegetable "plasma-skin" Ruhland arrives at the conclusion that the capacity for diffusion and the rapidity of diffusion of dye-stuff solutions in jellies, especially in gelatine jelly, run parallel "without exception" to the capacity of dye-stuffs to penetrate living plant cells; also that "the living cell resembles an ultra-filter operating at a high pressure by reason of its semi-permeable plasma-skin with respect to colloids," and likewise that "the dispersive power of the jellies of the plasma-skin constitutes the decisive moment for the capacity and rapidity of absorption."

Ruhland's views are highly esteemed and justly so, and we should probably have never thought of criticising them but for the circumstance that the facts proved by us with regard to the capacity for shrinking of the basic dye-stuffs and the capacity for swelling of numerous acid dye-stuffs have forced upon us the conclusion that the capacity for swelling and for shrinking and therewith the capacity likewise of jellies to liquefy, or to congeal. as well as to lessen or to increase the friction of the cell sap, must be one of the factors which exerts an influence upon the permeability, and especially too upon the "storage" and rapidity of storage of dye-stuffs.

[*We are obliged here to omit the detailed criticism made by the authors concerning Ruhland's methods and conclusions together with the elaborate tables which accompany it, merely giving their final conclusions.*—EDITOR.]

When we compare the permeabilities determined by Ruhland (which must be determined for basic dye-stuffs in other plant objects as well as for acid dye-stuffs) with the diffusion values obtained by me, we undoubtedly perceive that they largely coincide. In spite of this it is not possible to regard the penetration of plant cells by dye-stuffs merely as a diffusion in jelly—in other words as an ultra-filtration.

Among the basic dye-stuffs we will refer only to rhodamin B and Bismarck brown; it is well known that in many dye-stuffs the differences of diffusion are very great where gradations of permeability are not specified.

With respect to acid dye-stuffs we found very marked exceptions in the case of wool-violet and Martius-yellow. We may mention, also, methyl-orange and fast-brown G which diffuse readily but permeate with considerable difficulty. Eosin and phloxin and also erythrosin and Bengal-rose diffuse better than might be expected from their very low degree of permeability. Acid green, light-green S, and naphtol-green permeate readily and diffuse poorly.

The very circumstance that we found very different permeability values for basic and acid dye-stuffs (though making use of similar sections of plants) whereas the figures for the jelly diffusion of acid and basic dye-stuffs exhibit similar intervals, indicates that there are concerned impermeability influences other than jelly diffusion alone. We know that salt ions such as potassium, ammonium, etc., penetrate cells with comparative ease because of the fact that they have swelling properties (just as narcotics do); but we also know, on the other hand, that shrinking ions such as calcium, SO_4, or non-conductors such as varieties of sugar penetrate only with great difficulty. When we find, therefore, that basic dye-stuffs nearly always have a shrinking action, while on the other hand acid dye-stuffs mostly, or at least very frequently (and in increasing measure with the lapse of time) exert a swelling action, we can hardly avoid the conclusion that we have here the key to the different behavior of basic and acid dye-stuffs with respect to capacity for storage and rapidity of storage, and furthermore, that the properties of swelling and shrinking cannot be excluded from the problem of permeability. . . . We are of opinion that when dye-stuffs such as eosin, phloxin, erythrosin, and Bengal rose permeate less readily than they diffuse in jellies, it is necessary to take into consideration the shrinking properties of these dye-stuffs (these properties being greatest in the poorly permeating dye-stuff Bengal-rose).

JELLY DIFFUSION AND DIALYSIS.

[*This section begins with a table here omitted, giving the rapidities of jelly diffusion and dialysis as noted by various observers.*—EDITOR.]

An examination of the foregoing table justifies us in concluding that *the rapidity of gelatine diffusion is parallel in general to rapidity of dialysis.* Only in the case of neutral-red is there a slight difference. Furthermore, the dialysis values . . . are much less exact than the values of the jelly diffusion and are derived moreover, from various observers. According to Hoeber, guinea-green B dialyses rapidly, while according to our own observation guinea-green R diffuses very slightly in gelatine. The value concerned is 4(2).

According to Teague and Buxton dye-stuffs are arranged with respect to the capacity for diffusion in one per cent agar almost in the same sequence as in respect to their capacity for dialysis through a cellulose filter. Eosin, methylene blue, chrysoidin, and safranin diffuse strongly, Congo-red and azure-blue diffuse very slightly, and night-blue not at all.

While we by no means claim that the rapidity of diffusion and that of dialysis run parallel to each other without exception, the coincidence of values shown above leads us to conclude that the permeability of plant cells may be regarded quite as justifiably as a simple dialytic process, as it can be considered as a process of jelly filtration. We do not deny, indeed, the possibility that jelly filtration occurs in plants, but convincing proof thereof is thus far not at hand.

The analogy of the results given by gelatine, agar, and cellulose, justifies us in believing that for different colloids the same or nearly the same sequence of diffusing and dialyzing substances exists.

THE COLLOIDAL CONDITION OF DYE-STUFFS.

Ruhland has justly observed that the direct ultra-microscopic examination of dye-stuffs has laid bare many contradictions. Since dye-stuffs are frequently impure, containing small admixtures of sodium-sulphate, dextrin, etc., which influence the ultra-microscopic image, such contradictory results are not to be wondered at. In spite of this we are of opinion that more precise ultra-microscopic investigations are best adapted to furnish a concept of the colloidal condition of various dye-stuff substances.

Ruhland believes that certain indirect methods, like the

method first proposed by Hoeber of the precipitability of acid dye-stuff solution by varying concentrations of calcium chloride or nickel-chloride, as likewise the jelly diffusion methods of Bechold (utilizing the principle of ultra-filtration) are to be preferred, although these methods are certainly far from perfect.

Pelet-Jolivet correctly points out that the methods of precipitation are primarily related to a chemical exchange. The sodium salt of the dye-stuff is exchanged at least partially with the calcium salt or nickel salt concerned, whose difficult solubility will primarily influence the process. In spite of this we are also of the opinion that in general, or at any rate usually, the values obtained by this method admit of the conclusion as to the dispersive power, but the method should be controlled by the direct ultra-microscopic method.

The same restrictions must be applied to the principle of ultra-filtration.

If this principle be strictly accepted the measurements of diffusion would yield an exact measure of the dispersive power and if we admit further that the rapidity of diffusion and permeability always run parallel, we shall arrive at the theory advocated by Ruhland according to which the magnitude of the colloid particles is decisive with respect to the permeability. But this is really a revival of the old "sieve theory" of M. Traube—at any rate so far as colloids are concerned.

Attention must be called, however,—in opposition to the principle of ultra-filtration—to the alterability of the dispersing jelly through the substance added. If we filter through gelatine various dispersed particles of the same colloid or different colloids having the same degree of swelling or shrinking effect, we are justified in determining in this manner the relative magnitude of the particles, but if we try to compare dye-stuffs having a marked swelling effect with those having a marked shrinking effect, we shall inevitably arrive at false conclusions concerning the degrees of dispersive power. Thus for example, a dye-stuff of the eosin group may be only slightly colloidal, and yet in consequence of its capacity for shrinking it may take the place of a highly colloidal condition. In spite of these restrictions, however, which must be considered in estimating the value of the ultra-filtration method, we are of opinion that it is usually possible to obtain in this manner an approximately correct idea of the dispersive power of the dye-stuff colloid. However, Ruhland's "sieve theory" should be restricted in this case also by saying that the diffusion and permeability are influenced, not only by the magnitude of the particles but also by the capacity for swelling or shrinking of the dispersoid with respect to the dispersion medium.

MOLECULAR WEIGHT, COLLOIDAL CONDITION AND DIFFUSION, ETC.

In a work by Traube and Onodera it was shown that in aqueous solutions of free alkaloids sub-microns do not become visible until the molecular weight exceeds a certain minimum magnitude. Thus there is indicated a dependence of the colloidal condition upon the molecular weight; however it is pointed out that the molecular weight is not the only factor in question, but that constitutional influences are present, though, perhaps, of secondary character. It was not known at that time to one of us—namely Traube—that similar views had already been proposed with respect to dye-stuffs. Krafft has pointed out the significance of the molecular weight with respect to the colloidal properties of dye-stuffs. Buxton and Teague have shown furthermore that the capacity for dialysis and therewith the dispersive power, in spite of certain deviations, bear a quite unmistakable relation to the molecular weight; Wo. Ostwald has published in his volume of Colloidal Chemistry a table in which the same results are indicated.

[*Here follows a table which we omit showing the degree of parallelism between molecular weights and colloidal condition.* —EDITOR.]

To begin with we would like to call special attention to the fact that the jelly diffusion can by no means be regarded always as a measure of the dispersive power. We may also remark that the high molecular weight of the group: Eosin, phloxin, erythrosin, and Bengal rose, can be traced to the greater number of atoms of chlorine, bromine, or iodine; furthermore, the nature of the atom doubtless plays a part. With the exception of these dye-stuffs, however, it cannot be doubted that in general the capacity to form colloidal aggregates—as in the alkaloids—increases in proportion with the molecular weight, even though other influences cannot be excluded. This relationship between molecular weight and dispersive power is of the highest importance with respect to the principles of colloidal chemistry. . . .

CONCERNING STORAGE AND DYEING.

. . . The rapidity of storage is an exceedingly important factor. We will now enquire what factors are chiefly operative in causing a dye-stuff to be precipitated at a definite *locus* of the cells.

The reason that the basic dye-stuffs have a considerably greater capacity for storage than the majority of the acid dye-stuffs, is to be attributed above all to their property of producing a shrinking effect. The greater the shrinking effect exerted by the substance the less will be its need of a mordant in order to fix it. Dye-stuffs which have a swelling effect exhibit a tendency to permeate while those which have a shrinking effect have a tendency, on the contrary, to allow themselves to be absorbed. A dye-stuff having a strong shrinking effect, such as night-blue or naphtindon, naturally exhibits this tendency in a far greater degree than a slightly shrinking dye-stuff of great dispersive power, like methylene-blue, etc. Krafft has already pointed out that it is also true for highly colloidal acid dye-stuffs, like azo-blue and diamin-pure blue that they are capable of dyeing cotton without a mordant.

In our diffusion experiments in which 5 ccm. of 10 per cent gelatine were placed in small test tubes and covered with 1 ccm. of a 0.1 per cent solution of dye-stuffs, we found that after a lapse of eight days a complete clarification of the dye-stuff solution occurred in the aqueous superficial solution of azo-blue, isamin-blue, naphtindon, and new-blue, with a deposit of the dye-stuff upon the surface of the gelatine. We are here concerned with highly colloidal dye-stuffs which, like azo-blue, isamin-blue, and naphtindon, undergo no diffusion in the jelly, or which like new-blue diffuse very slightly.

An almost complete clarification with a dyeing of the gelatine surface was observed in the case of heliotrope, water-blue, fast-brown, Congo-red, fast-red, Nile-blue, Bordeaux, Victoria-blue, brilliant-Congo, and alizerin-saphiol. These are all highly colloidal dye-stuffs and the process of dyeing can be most clearly observed here. The more dispersive dye-stuffs, which diffuse more strongly in the gelatine do not exhibit this capacity for storage or else show it only in a slighter degree; furthermore it need scarcely be mentioned that in the absence of the gelatine phase even the highly colloidal dye-stuffs are not deposited. The gelatine surface exerts an attraction upon the particles of dye-stuff whether these be acid or basic, provided only the said particles are of sufficient magnitude. The particles become aggregated and form upon the surface of the jelly a cohesive layer of the dye-stuff of measurable thickness. But it must be emphasized that we are here concerned with a colloidal and not a chemical process, as is true in general of dyeing processes.

It is a known fact that the capacity for absorption of substances frequently bears a close relation to the activity of the surface. In the section following are contained the superficial activities of the dye-stuff solutions here investigated. It might be thought that a dye-stuff of great surface activity, e.g. rhodamin B would be absorbed in greater measure, in spite of its great dispersive power, than methylene-blue for instance; however, basicity also plays a part here and we lack technical information concerning the dyeing power of the various dye-stuffs as such, to enable us to express this relation between surface activity and storage capacity.

We are concerned naturally in the consideration of the dyeing capacity and storage capacity of dye-stuffs, not merely with the dye-stuff itself, but above all with the electric charge of the *locus* in which the storage takes place, with the presence of the substances which are found there, with the medium in which the dye-stuff operates, and particularly with the possible addition of a third substance to the medium involved.

We must, therefore, at once reject the hypothesis of those authorities who uphold the chemical theory of the process of dyeing according to which the fibers must contain basic or acid groups in order to absorb acid or basic dye-stuffs respecitvely. It is certainly true that when at the *loci* in question an-ionic colloids (like tannin) are found dye-stuff cations are there deposited and vice versa; but on the other hand the presence of free hydrogen ions at once accelerates the deposit of dye-stuff an-ions and on the other hand the presence of hydroxul ions accelerates that of dye-stuff cat-ions. It is well known in fact that it it customary in the technology of dyeing to add to the sodium salts of the acid dye-stuffs, assistant acids such as sulphuric acid, etc., or acid salts, while to basic dye-stuffs sodium carbonate, etc., are sometimes added.

[*We here omit a series of detailed experiments along this line, giving merely the definite conclusions of the authors.*—EDITOR.]

Taking everything into consideration we must again lay stress upon the fact that in our opinion the storage and dyeing process is colloidal in character and not stoichiometrical-chemical in spite of the partial decomposition of the dye-stuff salt. Definite influences are exerted by the nature of the dye-stuff, the respective acidity or alkalinity of the dye-stuff ion, the swelling or shrinking properties connected therewith, the dispersive power of the dye-stuff and apparently, also, the surface activity. A definite influence is exerted furthermore by the acid or basic reaction of the medium and the storage *locus* (limiting surface of the phase) as, likewise, the presence of colloids having opposite electric charges, which occasions a flocculent separation. All the influences which occasion a lessening of the dispersive power of the dye-stuff increase the absorptive power.

THE SURFACE TENSION OF DYE-STUFF SOLUTIONS.

[*We omit the lengthy table with which this section opens. It gives a list of basic and acid dye-stuffs with their surface tensions (determined by a stalagmometer), and in parallel columns the average duration of life of fish in a 0.02 per cent solution and of tadpoles in a 0.1 per cent solution.*—EDITOR.]

While the determination of the toxicities of dye-stuffs lies somewhat outside the scope of the present article we find it desirable to record the degree of toxicity with respect to both animals and plants of the various dye-stuffs examined. The results of the investigation of barley will appear shortly elsewhere; we give here only those respecting "Blitzfisch." Our investigations indicate that in basic dye-stuff solutions the surface activity is by no means a negligible factor. It is clearly connected with the complex magnitude which we term toxicity. The case is different with the acid dye-stuffs.

Two fishes each were placed in 0.02 per cent solutions of pricric acid, Martius yellow, Bengal-rose, Brilliant-walk-blue, erythrosin, tetra-cyanol, Congo-red, dioinin-blue, Guinea green, fast-brown, Bordeaux, acid-violet, methyl-orange, naphtol-yellow, acid-green, crystal poncean, quinolin-yellow, water-blue, and fast-red.

Picric acid and Martius-yellow proved very poisonous, killing the fish in 5 minutes. In fast-brown both were dead after 6 hours, and one was dead in brilliant walk-blue and in Bengal-rose each. Both were dead after 20 hours in tetra-cyanol and one each in crystal poncean and Congo-red. All the other fish were very lively.

Two fish each were then placed in 0.1 per cent solution (i.e. five times as strong) of the following dye-stuffs; cyanol, indigo-carmine, Orange I, naphthol green, light green, heliotrope, eosin, phloxin, azo-blue, azo-ruby, anthra-quinon-green, brilliant Congo, and thio-carmine. After 2 hours the fish in Orange I and in brilliant Congo were dead; those in phloxin still exhibited reflex motons. We conclude therefore that nearly all the acid dye-stuffs are quite non-poisonous, including those with great surface activity. . . .

SUMMARY.

1. Basic dye-stuffs in general exert a retarding action upon the rapidity of solution and an accelerating action on the rapidity of formation of a gelatine jelly. *Hence they have a shrinking effect.* As a usual thing the more colloidal the dye-stuff the greater the capacity for shrinking.

2. Acid dye-stuffs in many cases accelerate the rapidity of solution and retard that of the formation of a gelatine jelly. *Hence they have a swelling effect in many cases.* However there are many also which have a shrinking effect (Bengal rose, erythrosin, azure blue, etc.).

3. Diffusion tests in gelatine show that in general, but by no means always, the capacity for and rapidity of diffusion of dye-stuffs run parallel to the permeability in plant tissues, but that we are not justified in regarding permeability as a simple process of jelly diffusion—the less so, since it has been shown that the capacity for and rapidity of dialysis through paper filters, etc., likewise usually run parallel to the capacity for and rapidity of jelly diffusion and permeability.

4. In general the greater or lesser capacity for jelly diffusion, and therewith the principle of ultra-filtration, may be regarded as a measure of the magnitude of the colloid particles, but this is by no means always so, since shrinking and swelling substances constantly alter the medium.

5. As in the alkaloids, so also in the dye-stuffs the dispersive power is primarily dependent upon the molecular weight. The capacity of substances to form colloidal aggregates is accordingly chiefly a function of the molecular weight.

6. The capacity of dye-stuffs to exert a shrinking or swelling effect is a factor which must be taken into account in the most various problems of biology as well as in the theory and technology of dyeing. Swelling favors permeability as a general thing, while shrinking favors storage. The problem of permeability requires consideration of this new factor for its solution.

7. New views with respect to the question of dyeing in general are based upon experiments in gelatine diffusion; among other things the effect of the addition of acids to acid dye-stuffs and of alkalies to basic dye-stuffs may be made clear. A dyeing process is in general colloidal in nature and not a chemical process governed by stoichiometric relations.

8. Measurements of the surface activity of dye-stuff solutions and determinations of the degree of toxicity show that in the case of basic dye-stuffs there is a definite (though not exclusive) connection between surface activity and toxicity with respect to tadpoles and fish.

NEW METHODS OF PREVENTING THE PROPAGATION OF TYPHUS.

A NEW "de-lousing" method has been developed by the Pasteur Institute of Paris and applied at its various centers throughout France. Clothing, bedding, etc., which are to be treated are hung up in a large oven or chamber, heated to 45 degrees C. and containing 20 c.c. of chloropicrine per cubic meter of air (i.e. 1 to 50,000). Chloropicrine is well known as one of the asphyxiating gases used in the war. France possesses a considerable stock of this product, which like many others of its kind, can now be turned to a good advantage. Prof. G. Bertrand, of the Pasteur Institute, has recently examined the disinfectant and parasite-destroying properties of this substance. After a 20-minute treatment in this chamber, the parasites are entirely destroyed throughout the whole thickness of matresses and clothing, and the latter can be worn immediately afterwards without having suffered in the least. The present method, which is due to a careful research on the part of specialists, will render the greatest service against the propagation of typhus.

Commercial Fertilizer

Brief Discussion of Its Functions and Methods Used in Its Manufacture

By Thomas R. Harney

FOR years past, except for a period during the early part of the war there has been a steady increase in the amount of artificial or "commercial" fertilizer used in the United States, and now that we are preparing to get settled down after the turmoil, it is probable that this increase will continue. This is especially probable in view of the present difficulties with the quantity and quality of farm labor, and of the growing agitation for intensive farming, since it can be shown by agricultural experts that in many cases the judicious use of the proper artificial fertilizer will serve the double purpose of saving labor and of increasing crop yield. Since successful crop production, as a factor in the reduction of living costs, touches all of us, a brief discussion of the functions of commercial fertilizer and of its methods of manufacture may be of interest.

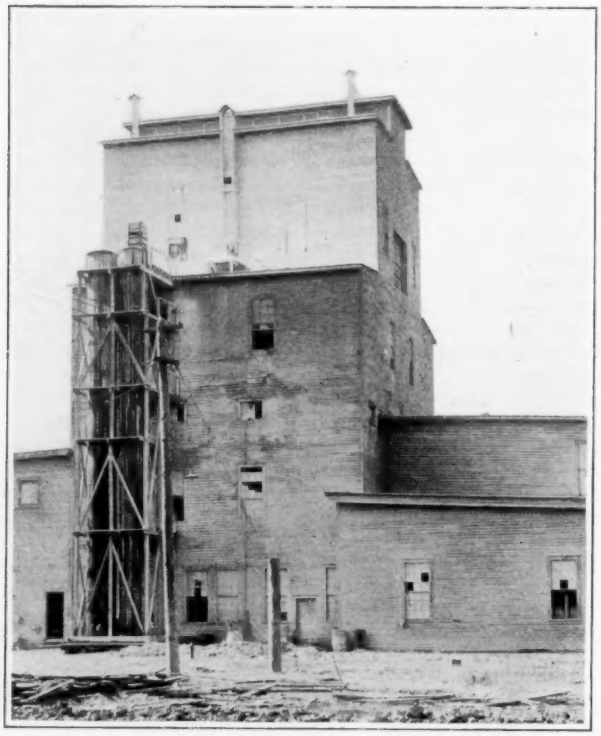


FIG. 1. ACIDULATING BUILDING WHERE ACID PHOSPHATE IS MADE

In the production of any crop there are three principal elements which the soil must supply, namely, nitrogen, potassium and phosphorous. Through long established custom, in the fertilizer business these elements are usually known as "ammonia," "potash," and "phosphoric acid," and for the purpose of being conventional I will so refer to them, though scientifically the names are incorrect, being the names of compounds containing the corresponding element, which compounds are seldom present to any large extent in fertilizer.

Certain soils, particularly those of virgin nature, may be sufficiently rich in all three elements; others, either naturally or through exhaustion by continued cultivation, may need the addition of one, two or perhaps, all three elements from some outside source. The office of commercial fertilizer is to aid the natural farmyard manures in supplying this lacking plant food, in the proper proportions for a given soil or a particular crop.

The nitrogen used in artificial fertilizers is supplied from various sources, some of them inorganic, as in the case of nitrate of soda and sulphate of ammonia, and some organic as tankage, dried blood, fish scrap, cottonseed meal, etc. Nitrate of soda is found in Chile, and in practically no other place in the world. Its preparation for use consists merely in "leaching" or dissolving in water to free it from insoluble impurities and in the subsequent evaporation of the water solution to produce the crystallized salt. Sulphate of ammonia is produced by absorbing in sulphuric acid the ammonia gas which is given off during the manufacture of coal gas in by-product coke ovens or gas producers. During the war the manufacture, or rather the recovery, of this material was considerably increased, due to the fact that a large part of the available nitrate of soda supply was required for the manufacture of nitric acid. I say the "recovery" was increased, for we have always produced many thousands of tons more than we have saved, allowing it to escape all over the country from the chimneys of our houses and our power plants, and from the vent-holes of our old-time "bee-hive" coke ovens. Sulphate of ammonia is only one of the by-products of the distillation of coal, for the loss of which future generations will jeer at us as a race of barbarians.

There is another source of ammonia, which has developed rapidly in the last few years, and which seems destined, perhaps, to play a very important part in the future. It is known as "cyanamid," and is the product obtained by what is, to date, probably the most successful of the "air-nitrogen" processes. The details of its manufacture would require too much space for this brief discussion, but it may be said in passing that by the aid of the electric current the producers of cyanamid have tapped what appears to be an inexhaustible source of nitrogen. Every ounce of that element which occurs in the cyanamid of commerce has come from the atmosphere, and as the atmosphere is nearly eighty per cent nitrogen, it remains only to bring the process to the highest possible state of efficiency to have at hand an ample supply of nitrogen for fertilizers—or explosives.

The other organic ammoniates are too numerous to permit of complete discussion here, but in most cases their names indicate the sources from which they are derived. During the last year or so the use of some of them as stock feeds has become so extensive as to make the current prices almost prohibitive so far as fertilizer manufacture is concerned.

The sources of potash in the United States are also too numerous to allow a discussion here of its preparation. The "American Fertilizer Handbook" for 1919 says: "Production of potash in the United States during 1918 came from seven different sources, as follows: Natural brines, alunite, dust from cement mills, molasses distillery waste, waste sugar refinery water, and wood ashes. The amount from other sources was negligible." Alunite is a potassium bearing mineral found in some of the western states, and kelp is a sea-weed. The other sources are self-explanatory. Of the potash producing capacity of the United States, fifty per cent is represented by the natural brines of Nebraska and twenty-eight per cent by other brine lakes. (The American Fertilizer Handbook, 1919.)

Since practically all commercial fertilizers contain acid phosphate as their source of phosphoric acid, the manufacture of this compound will be discussed at somewhat greater length.

RAW MATERIALS.

The raw materials necessary for the manufacture of acid phosphate are sulphuric acid and "phosphate rock." The

former is sometimes manufactured in a plant operated as a department of the fertilizer works, and sometimes bought and shipped in from the outside. In either case it is used in the form of a water solution, usually containing about sxity-five per cent, by weight, of sulphuric acid—the approximate strength of "chamber acid" direct from acid chambers. The phosphate rock is mined, in the United States, principally in Florida, Tennessee, and South Carolina, though there are large, undeveloped deposits in other states, especially in the west. It occurs in various forms, from the very hard "blue rock" of certain deposits in Tennessee, to the gravel and pebbles of Florida "land-" and "river-pebble." It is usually crushed, washed, and dried at the mines being delivered to the fertilizer plant, sometimes ready for the pulverizers, and sometimes requiring a preliminary rough crushing.

There is some difference of opinion as to the exact origin of the phosphorous in phosphate rock, but it is pretty generally agreed now that it was originally of an organic nature, such as animal remains, bones, excreta, etc. The chemical composition varies almost as much as the physical form, but most plants in the country operate on rock containing from sixty-five to seventy-five per cent of tri-calcium phosphate, or "bone phosphate of lime" as it is commonly called.

CHEMICAL BASIS OF MANUFACTURE.

The chemistry involved in the manufacture of phosphatic fertilizer is based upon the fact that there exists a series of compounds formed from phosphoric acid and lime, all of which contain these two substances in varying proportions, but which have very different characteristics otherwise. The two of these compounds which are of particular interest from a fertilizer standpoint are known technically as "tri-calcium-phosphate" and "mono-calcium acid phosphate," the former being the bone phosphate of lime mentioned above as occurring in phosphate rock, and the latter the "acid phosphate" of commerce.

The chemical formulae for these compounds are, respectively, $Ca_3P_2O_8$, and $CaH_4P_2O_8$. As their names indicate, the former contains three atoms of calcium (Ca), equivalent to three molecules of lime (CaO), to one molecule phosphoric anhydride (P_2O_5), while the latter has only one molecule of lime to one molecule of the anhydride, but in addition has four atoms of hydrogen. The presence of the hydrogen gives to the compound the title "acid" phosphate.

By the action of the proper amount of sulphuric acid tri-calcium phosphate may be converted into the mono-calcium compound, or to express it in a more scientific manner, four atoms of hydrogen are substituted for two atoms of calcium. The displaced calcium forms calcium sulphate ($CaSO_4$) with the sulphate (SO_4) group of the acid, and this calcium sulphate then plays an important part in the conditioning of the mass through the taking up of two molecules of water by each molecule of calcium sulphate, to form gypsum ($CaSO_4 2H_2O$), thus serving as a dryer.

Besides the differences in constitution shown above, mono-calcium acid phosphate has the important property of being readily soluble in water, which tri-calcium phosphate is not. In this fact lies the value of acid phosphate as a fertilizer, since when placed in the soil it becomes immediately available for plant food through the action of moisture. On the other hand, tri-calcium phosphate, or raw phosphate rock, while probably rendered ultimately available through the action of the dilute acids usually present in soils, would require considerable time, perhaps years, to furnish as much plant food as the same amount of phosphorous in the form of acid phosphate would provide in a few days or weeks.

THE PROCESS.

Fig. 2 is a flow sheet of the acid phosphate process, showing in outline the steps which are taken to convert raw phosphate rock into commercial fertilizer.

When the rock arrives at the plant, it is sometimes ready for the pulverizer, and sometimes requires a preliminary rough crushing. In case the crushing is necessary the usual apparatus is the familiar jaw crusher, so set as to produce material which will pass a one-inch ring. From the crusher, or from the cars, as the case may be, the rock is fed to the pulverizer shown in Fig. 4, where it is reduced to dust. In the past it has been customary to be satisfied if this dust be sufficiently fine for about 80 per cent of it to pass a 60-mesh screen (i.e., a screen having sixty meshes to the lineal inch, 3,600 to the square inch) but the modern tendency is to work toward a greater fineness. A good many of the later plants are using dust 90 to 95 per cent of which will pass a 100-mesh screen.

The pulverizer, or "mill" shown in the illustration depends solely upon centrifugal action for its grinding. As may be seen by an examination of the picture there is a central shaft, driven by a pinion and large ring gear. Attached to this shaft, inside the casing of the mill are three arms, forming a "spider," and at the end of each arm, suspended in trunnions, is a "roller." The main part of the roller is approximately two feet long, with the roll proper at the lower end,

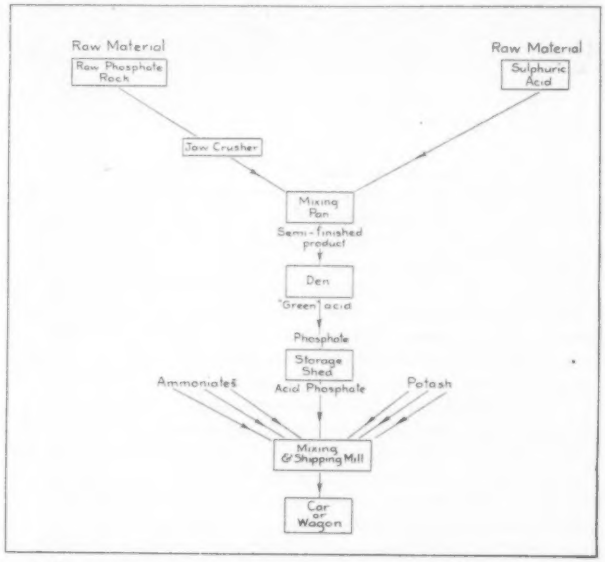


FIG. 2. STEPS IN THE PROCESS OF CONVERTING RAW PHOSPHATE ROCK INTO COMMERCIAL FERTILIZER

and as the shaft is revolved, the centrifugal force causes this roll to press against a "bull ring" on the inside of the mill. The rock is fed to the inner chamber of the mill by means of the spout shown at the right of the ring gear. This spout, at its upper end, leads to a rock bin to which the rock is raised by a bucket elevator.

Just back of the bull ring, and between it and the casing, is a fifty-mesh screen, and when the dust is sufficiently fine to pass this screen it drops through a chute into a screw conveyor operating under the mill, and is delivered to the boot of another bucket elevator which raises it to the top floor of the building. This elevator can be seen, faintly, at the extreme left of the picture.

Some pulverizing units have the screen and mill separate, the dust being elevated from the mill, screened and the oversize automatically returned to the mill for another grinding, and where the extreme fineness mentioned above is desired, air separation is used. This consists in raising the dust from the mill through pipes by means of a draft of air, and then suddenly allowing the air to expand in a "dust collector." This expansion, of course, lessens the velocity of the air current, and the coarser particles of dust are dropped while the finer and lighter particles pass on to the dust bin. The coarser material returns to the mill for another grinding.

FIG. 3. MIXING THE DUST WITH SULPHURIC ACID

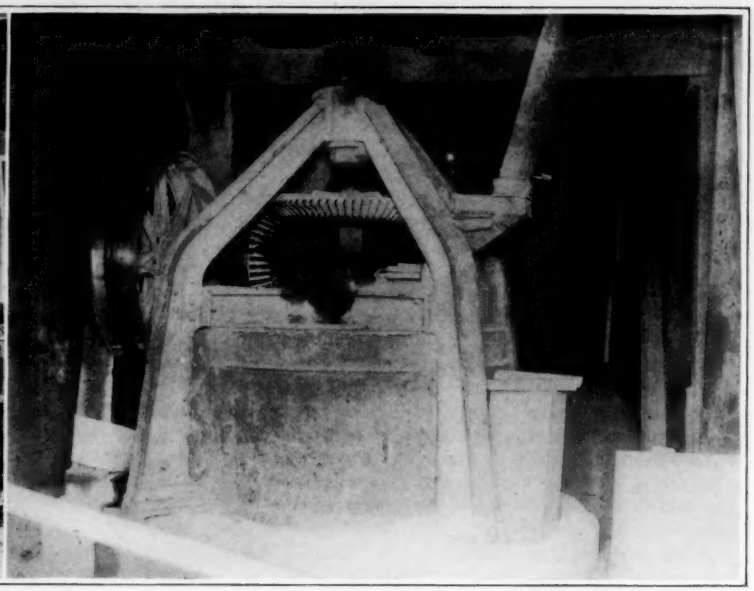


FIG. 4. THE PULVERIZING MACHINE WHICH REDUCES THE CRUSHED ROCK TO DUST

The next step in manufacture is the mixing of the dust with sulphuric acid. This is carried out in the "mixing pan" shown in Fig. 3. This is a shallow, cast iron pan, the stationary upper part of which can be seen in the illustration. The lower part extends beneath the floor. As may be seen a geared driving ring completely surrounds the body of the pan. This is driven by a pinion, concealed behind the stanchion at the extreme right of the figure, and in revolving rotates the pan. The object of course, is to give a thorough stirring to the contents, and this purpose is still further served by the "plows," the driving gear of which is shown. A shaft from the beveled ring gear, shown just behind the post at the right center of the illustration, extends downward through the stationary top of the pan, and ends in a four-armed spider. To each arm, and extended still further downward into the mass to be mixed, is a cast steel bar, chisel pointed, and with the point bent slightly forward in the direction of rotation of the spider. As this spider revolves, and the material in the pan is carried past by the rotation of the latter, this material is given a very thorough mixing. When it reaches the other side of the pan it meets another plow, hidden, in the illustration, behind the hopper, which revolves in the opposite direction from the first one, so that a very few rotations of the pan serve to complete the mixing process.

In the operation of "mixing," also known as "acidulation," the dust is drawn by gravity from the dust bin on the next floor, into the large weighing hopper, shown in the center of the illustration. This hopper is shown empty; when full the weight arm in the foreground rises in its slot. During this operation, an approximately equal weight of about sixty-five per cent sulphuric acid is being drawn into a measuring tank, not shown in the figure. When both are full, they are run into the pan simultaneously, the dust by opening the slide shown at the bottom of the hopper and the slide shown in the stationary top of the pan, and the acid by opening a valve in the lead pipe line which can be seen crossing over to the center of the pan, behind the stanchion at the right. It usually requires only about a minute after both materials

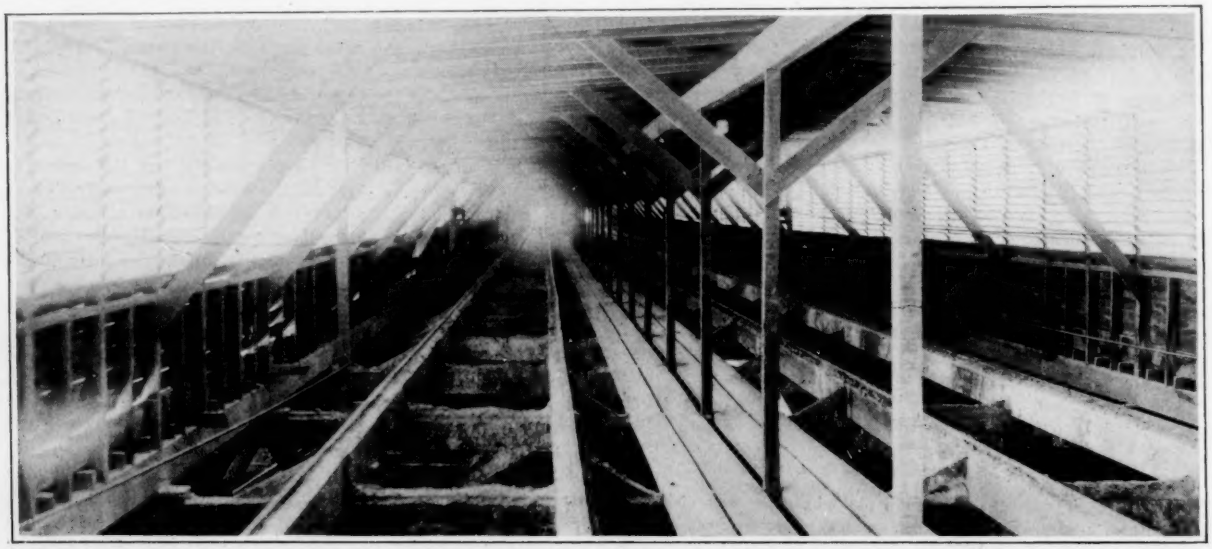


FIG. 5. THE TRACK UNDER THE DEN. THE GREEN PHOSPHATE FALLS THROUGH SLOTS IN THE FLOOR OF THE DEN INTO DUMPING CARS

are in the pan for the mixing to be complete. The operator watches the action through the dust charging hole, and when it is completed he raises a plug, the operating handle of which can be seen just over the acid inlet pipe, allowing the mixed mass to flow out through the bottom of the pan into what is known as the "hot den" or simply the "den."

This den is merely a strongly constructed room, capable of being tightly sealed except for one opening connected to a large exhauster which draws off the steam and gases generated by the action. The function of the den is to conserve the heat generated and to keep the reacting materials pressed together until the action is complete. This action, of course, commences as soon as the acid and dust come in contact in the pan, but it has been found to continue for some time after that.

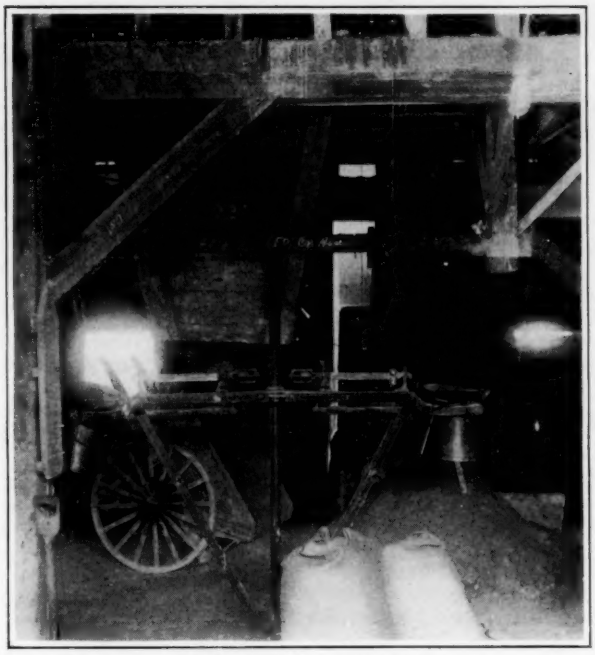


FIG. 6. THE MIXING PLANT

After from twelve to twenty-four hours in the den action has practically ceased, though it may go on slowly for several days or weeks, and the material, now "green" acid phosphate, is withdrawn. This withdrawing is accomplished in various ways—sometimes by conveyor, sometimes, in the very old plants, by hand, and in some of the most modern plants by having the den top removable, allowing the den to be emptied by an electric crane and bucket. In the particular plant shown in the illustrations, there are two slots in the bottom of the den, covered by loose boards while the den is being filled, but which can be opened when desired. The green phosphate is raked through these slots by hand and falls into dump cars operating on the track shown in Fig. 5. As can be seen these tracks extend over the storage piles, and the car when filled is drawn out over the pile by the cable shown at the left of the figure. This cable operates on the endless chain principle over a large motor-driven pulley, and when the car reaches the pile which is being built up, a trip block automatically opens it, allowing the contents to fall on the pile. As the car comes back the same trip block closes it, so that it is again ready to be filled as soon as in position. Until the introduction of the electric crane and bucket in the fertilizer business, this was probably the most efficient method of emptying the dens.

Fig. 7 is a view in the storage and shipping shed, and shows a pile of acid phosphate in storage. The length of time which this material remains in the shed depends somewhat upon the time of year at which it was manufactured—whether near to or far from the planting season. Most operators, however, prefer that it "cure" or dry for two or three weeks before any attempt is made to ship it, since before shipping or when mixing with ammoniates of potash-bearing materials, it must be put through a "disintegrator" or "clod-breaker" to break up the large clods shown at the foot of the pile in the illustration.

There are many methods of carrying out this shipping and mixing from the old hand methods of some of the smaller plants, to the highly efficient "batching" hoppers and automatic weighing machines of the large modern works. Where the acid phosphate is to be shipped out as such, without any added ammonia or potash, it is simply put through a disintegrator and broken up so that it will pass a three or four-mesh screen. It is then ready for shipment.

The method of mixing in the plant shown in the illustrations, which might, perhaps, be considered a good average of all methods, is as follows: Acid phosphate, one or more ammoniates, and one or more potash-bearing materials are weighed up in wheelbarrows, on small platform scales. The calculations of the amount of each material are a simple matter of arithmetic, the chemical analysis of each, and of the desired mixture being known. When weighed they are dumped into the

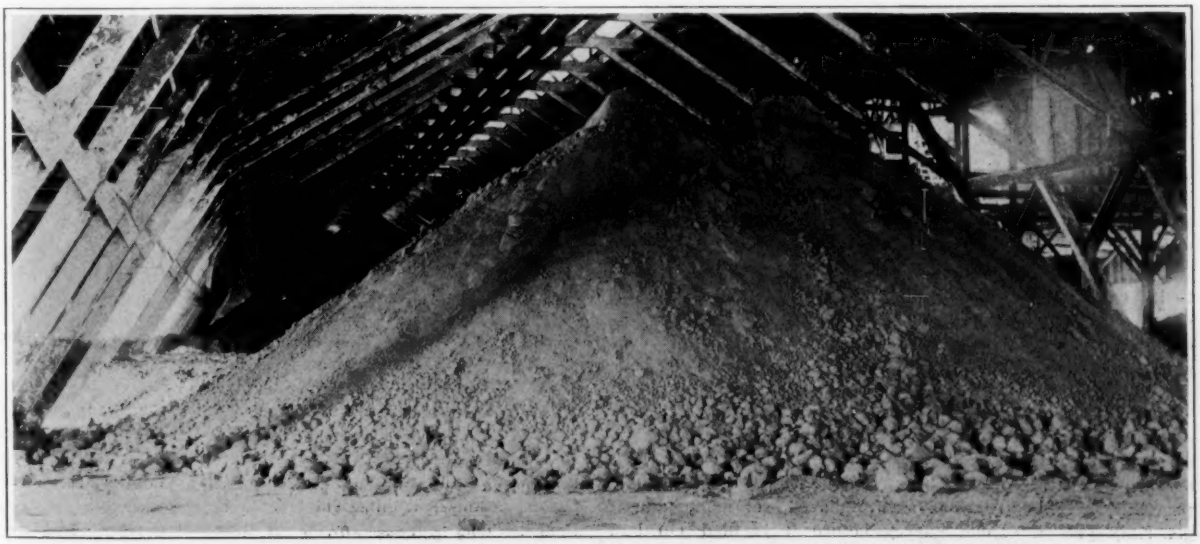


FIG. 7. THE STORAGE AND SHIPPING PLANT SHOWING PILES OF ACID PHOSPHATE IN STORAGE

boot of an elevator, the housing of which can be seen, with the sunlight falling on it, just back of the two bags in Fig. 6. The elevator raises it to a disintegrator at the top, and from there it goes over a three or four-mesh screen, the over-size being returned to the bottom of the elevator and sent again through the disintegrator. The material which passes the screen is sent to a mixer, very similar in construction and operation to the ordinary batch mixer, where it is given a thorough mixing. It is then delivered to the hopper shown in the upper left of Fig. 6.

From this hopper it is withdrawn and put into bags. The bagging is done by means of the bagging scales shown in the figure. The hoop shown on the funnel-shaped attachment at the end of the scale arm can be clamped around the neck of a bag in such a way that the weight of the bag and contents will support it. When the bag is full—usually 200 pounds of fertilizer—the hoop is raised by a sharp blow and the bag drops off to be tagged, sewed and loaded in car or wagon for shipment.

A PRACTICAL METHOD OF FILING DATA FOR REFERENCE.

By J. Madison Taylor, A.B., M.D.

The plan here offered has been in use many years by me and my friends. It includes provision not only for unanimity in the assembling of choice data to be used by the collector, but can be lent to any one else. When the death of an industrious collector occurs, his data should be available by any one else working on similar lines. This last point, the ultimate disposition of valuable material, deserves especial attention.

And first is uniformity of method in the selection, arrangement and classification. My plan of procedure of assembly and bestowal might be agreed upon and adopted until a better one should offer. A considerable group of research workers would thus become able to interchange data, and to mutual advantage. This system has been found practicable among a group of my friends not all interested in medicine, but in correlated subjects such as genetics, psychogenetics, sociology, anthropology, and human economics. So excellent are some of these collectanea that we would deplore their dispersal or loss.

In my system the simple device is used of an ordinary commercial vertical filing case 12 inches by 16 inches. Wood material preferred as safer as a "flash fire" protection. This system or container is convenient for filing a full flat sheet, deleted from a medical weekly, 8½ inches by 11 inches. The standards are removed and the full sheet taken out. Related sheets are then clipped together and inscribed on the right side (which thus appears *up* in the folder, hence the inscription catches the eye). They are grouped in a threefold manner, thus: (1) a general classification; (2) a particular grouping; and (3) the specific topic all in manilla folders. More often the general subject is the only one stated. These are then filed by a secretary and await revision and disposition. These excerpts are taken from publications differing in size, but the maximum space of the commercial filing case suffices for medical and most other publications, scientific magazines and the like, from which material is taken.

I find it convenient to use three different colored folders to indicate (1) the general subject, a sort of "omnium gatherum" of heavy buff (manilla), (2) a pink one for selected or grouped subjects, and (3) a blue one for the particular aspect of the subject under consideration and also such memoranda, notes, partial manuscripts as should be kept together.

In the first reading of a journal my plan is to merely survey each article, to determine whether the subject or caption interests or not. Often one finds some parts of use, or some observation or hint, which I mark by a system of blue or red pencillings. This article is then removed, set aside, and it generally gets a second survey before it is filed (in buff manilla) and half the time is later, and should be, rejected. If it proves choice or suitable, it is further inscribed and goes into a pink, or even a blue folder. This routine, by the way, occupies so little time that eleven journals are disposed of and kept up to date with no waste of effort, now that the habit has become almost an automatic doing.

When I desire to inform myself on a special topic I can turn to the general subject (which generally occupies several manilla folders) and rapidly pick out special material to be placed in a pink folder, and when in haste I can run over these and get enough selected data for a blue one, and go to work. Note that materials thus assembled are original articles or at least first-hand abstracts, and among these will be found references to other articles or to text books and the like.

In providing space for general subjects some large topic may occupy an entire drawer, others only half a drawer. The lettered spaces can be reinscribed or specially labelled to suit. It is well to put all the manilla folders at the far end of a space, and together, since they are subject to constant revisions and rejections. The folders fluctuate in bulk as they become filed, and as distributions or rejections are made.

A number of useful devices were developed as experience grew but this outline may afford hints enough. Each individual making use of the system will devise yet others. The chief points I wish to emphasize are *the desirability of the adoption of some uniformity in arranging literary material*, also the wisdom of preserving such material after one has taken pains to assemble so much, he shall then be able to pass the collection on to others. It would seem to me that one who has made a considerable repository should notify the librarian of some central or local library specifying the subjects he has covered and any other pertinent facts, such as how large the stock is and what special topics the collector has been interested in. It may well happen that there is also a good deal of half finished, or pretty well completed manuscript. The title of these manuscripts should also be available. I keep such a memoranda, or table of contents in a blue folder. Should I pass out *now* my "heirs and assigns" would probably cast all this material in the rubbish heap. Another or many others however, might be most glad to get this data. I certainly would be glad to have had access to similar reservoirs and manuscripts.

STARCH FORMATION IN LEAVES, AND PHOTOGRAPHIC PRINTS.

Photographic prints from negatives can be made upon the leaves of living plants, thus putting in evidence the formation of starch in the leaves under the influence of solar light. The experiments can be carried out with especially good results by employing nasturtium leaves for the purpose, since these are found to have the desired qualities such as a good flat surface, thin substance and absence of small hairs on filaments, and these leaves will readily become discolored through the removal of the chlorophyl. Suitably chosen leaves are wrapped about with black paper in such manner as to protect them from the light for about two days, in which case all the previously existing starch is absorbed. Then the leaf is exposed to the sun for an entire day under a good strong negative, a portrait for instance, and the starch will now be formed anew at the expense of the carbon dioxide and water vapor of the atmosphere in the parts which are exposed to the sun, in quantity depending upon the strength of the light, which of course depends in turn upon the variable thickness of the negative. The leaf is thereupon cut off from the plant, scalded for one or two minutes in boiling water, and then placed in a bath of alcohol until it becomes discolored, since the chlorophyl dissolves in the alcohol. After this treatment, the leaf is dipped into a bath of iodine water diluted to about the color of strong beer, and the starch will become colored a blue-violet hue, thus forming a positive image. The process affords an interesting result and also sets forth the part played by the chlorophyl.

Fresh Information Concerning Yeast

Research at the Berlin Institute of Fermentation and at the Mellon Institute at Pittsburgh

PERHAPS the plant which has been longest cultivated by mankind is the yeast plant, although it is only in comparatively recent years that it has been recognized as being a plant, and it is still more recently that the nature of its activities has been understood; still, fermented products were doubtless used long before agriculture began. Extensive researches with respect to yeast have been occupying men of science in various countries during the last ten years particularly. Some of the results of these researches have already been laid before the readers of the SCIENTIFIC AMERICAN[1] especially with regard to the work done in Germany concerning yeast as a valuable food material, as a possible substitute for bone, ivory, etc., and as a source of fats, sugar and protein derived directly from substances. It is the purpose of the present article to supplement this information on the one hand by an account of the latest available knowledge concerning the researches conducted by the Berlin Institute of Fermentation with regard to the mineral yeast so loudly heralded, i.e. yeast grown from inorganic substances instead of being obtained as a by-product from beer, and on the other by a *resumé* of the work done at the Mellon Institute respecting the improvement in the quality of bread by the addition of certain mineral compounds which furnish a portion of the nutriment required by the yeast. As will be seen the German researches—more ambitious than those conducted in this country—while eminently successful in the laboratory, are as yet a failure economically. Whereas the group of chemists at the Mellon Institute have succeeded brilliantly in both bettering the quality and lowering the cost of bread by means of mineral nutriments for the yeast plant.

Yeast is a fungus which is very simple in organization. It consists of microscopic oval cells, three or four microns in length which multiply by budding and readily separate from each other. Yeast does not produce alcoholic fermentation directly but only under special conditions through the intervention of various disastases which it secretes. In normal conditions, i.e. when it is cultivated in the air it secretes only sucrase and it inverts sugar without causing fermentation. In this case it breathes like an ordinary plant, absorbing the oxygen of the air, setting free carbon dioxide, and consuming only the comparatively small quantity of glucose which it requires for its nutrition and doing this exactly like any other fungus which is not an alcoholic ferment.

But as soon as the yeast is deprived of air its respiration ceases and the secretion of zymase (a diastase having the property of breaking up glucose into alcohol and carbon dioxide) begins; the result of this is alcoholic fermentation. In this latter case the cell acts as a ferment and the cellular mutliplication is less abundant than in the first case.

The yeasts employed in breweries are the cultivated yeasts belonging to the species *Saccharomyces cerebisiae;* after fermentation they are deposited at the bottom of the vat, where they can be recovered to be employed again. Since they multiply during the process of fermentation there always remains under normal circumstances a certain excess which is used for preparing bakers' yeast.

* * * * * *

When it was first proposed to make use of yeast for human food and animal fodder in Germany, the excess product derived from the brewers was employed, being dried, sterilized, and if necessary freed from its bitter flavor. This product was of great service dating from November, 1914; when employed as cattle food it took the place of 60 per cent of the protein previously furnished by imported fodder in the form of cereals, hay, oil, fish meal and dried meat. This dried yeast contains from 6 to 10 per cent of water, from 50 to 60 of proteins, from 2 to 4 per cent of fatty substances, from 22 to 35 per cent of organic matters of non-protein character (especially of carbohydrates, of which 20 per cent on the average consists of glycogen), and finally of from 5 to 11 per cent of mineral ash, 2 per cent of the latter being phosphated substances. From 78 to 88 per cent, varying according to the animals concerned, are assimilable.

Brewers' yeast either fresh or dry has long been employed in medicine, especially in the treatment of boils. Invstigation has proved that the curative virtues of this are not due to the fact that it contains living substances, the "figured" ferments diastases, zymases; for the sterilized product retains all these medicinal values. When used as a human food, yeast can be consumed in amounts of as large as 100 gr. per day.

Germany contained not less than 80 factories for the drying of yeast. The dried yeast sold to begin with for 28 marks per 100 kg., but its price rose to 80 marks. It is dried in the same manner as milk in the preparation of powdered milk, i.e. by depositing it in a thin layer upon revolving cylinders heated by steam and provided with scrapers.

The manufacture of this yeast was checked when the breweries went out of commission because of the lack of raw material. These yeasts from the breweries were cultivated of course by the second method of proliferation described above.

Yeast cultivated by the first method in purely mineral mediums has received the name of mineral yeast. The possibilities of obtaining this so-called mineral yeast was demonstrated long ago, by Pasteur in particular. But in Germany the question was more urgent. It was necessary to produce the yeast rapidly and in great quantities, and it was also necessary that it should be as rich as possible in assimilable products.

After a dilute aqueous solution containing sulphate of ammonia, phosphate of potassium, salts of lime and of magnesia, and sugar (molasses) is planted with a very prolific yeast and is furnished with a sufficient amount of air, the yeast will develop rapidly without fermentation and without producing alcohol.[2] This yeast separated by a filter press and then dried is mineral yeast.

The raw materials which it is possible to employ include:

1. Instead of molasses the residual waters from the sugar houses, which contain not only a certain amount of sugar but also nitrogenous substances and salts of potash.

2. The residual waters of starch-works, which contain besides sugar nitrogenous compounds and mineral salts of nutritive value for yeast.

3. The residual lyes remaining from the manufacture of cellulose paste by the bi-sulphite process; these contain both sugars and nutritive salts.

4. Urine and purin, which serve particularly as a source of nitrogen.

All of these raw materials have been thoroughly tested since 1916, and have been found to yield materials readily, but in the laboratory alone and in industrial tests (as much as 30 cm. of the solution ever in operation at one time), abundant quantities of a yeast which animals become easily

[1] Transforming Sugar Into Proteins and Fats, *Scientific American*, Vol. 113, p. 446.

Deriving Fat from Yeast, *Scientific American*, Vol. 114, p. 101.

Buttons as a By-product of Yeast, *Scientific American*, Vol. 115, p. 423.

Dried Beer Yeast as an Article of Food, *Scientific American*, Vol. 79, p. 311.

[2] At any rate this is true in theory; in practice, however, when yeast is cultivated in purely inorganic mediums the proliferation begins with difficulty and proceeds slowly; while the reason for this is as yet unknown, it is probably due to an excess or a lack of some one of the salts. When yeast is cultivated in any sort of must on the contrary, such as that used in breweries, the proliferation begins at once and continues with great rapidity.

habituated to provided it be added to other foods to which they are accustomed.

Unfortunately genuinely industrial and commercial attempts at manuafcture, which took place during the sugar campaign of 1917, 1918, were a complete failure. It had been expected that 99 per cent of the sugars employed could be transformed in the course of from 6 to 8 hours into a dry yeast containing only 10 per cent of water. However, it was found that to accomplish this abundant aeration was required, and this could not be obtained except by the use of such powerful bellows as to render the process impossible from the technical and economic point of view. Furthermore when without the aeration the content of the yeast with regard to the proteins, already considerably less than in beer yeast, was reduced from 50 to 35 per cent, a considerable fraction of the combined nitrogen in the raw materials was lost; in fact, in the form of free nitrogen it passed into the atmosphere in the gaseous state.

Later attempts were successful in reducing the blowing required by means of a new method and the distribution of air upon the yeast within the technically acceptable limits, but the resulting yeast utilizes only 82 per cent of the sugars employed. These results remain to be carefully verified so that thus far the process cannot be regarded as commercially successful. The objection has been raised that it would be more advantageous to make use of the raw materials listed above either in the form of cattle food or as fertilizing material. The answer to this is that while this would certainly be a better form of utilization of the raw materials, it would subject their value to the uncertainties involved in farming, namely, the changes of the weather and the various diseases to which the cattle are subject, to say nothing of the fact of the much greater length of time involved.

Furthermore, mineral yeast is far from being worth as much as brewers' yeast. When dried its content of nitrogenous substance is rarely as high as 50 per cent; that of carbohydrates is also less; while that of water and mineral salts is much higher. Finally, comparative experiments with regard to its digestion and assimilation by animals and by men, either with or without the removal of the bitter taste, show that the total percentage of assimilation is always less, sometimes considerably so; for each of these groups are food substances, especially the fatty matters.

We are indebted for the data in the preceding paragraphs concerning the German process and results to an article in the *Chemiker Zeitung* of Berlin an abstract of which appears in a recent number of *Le Génie Civil* of Paris.

In 1911 one of the largest bread-making concerns in the United States, having bakeries in several cities, established a fellowship in bread-making at Mellon Institute, Pittsburgh. The work was continued for several years, with highly gratifying results, since the quality of the product was both improved and standardized, while the cost was lowered. These happy consequences were chiefly due to the furnishing of certain mineral substances which acted as a food supply for the yeast. The investigations in question were carried on by Messrs. Henry A. Kohmann, Charles Hoffmann, Truman M. Godfrey, Lauren H. Ashe, and Alfred E. Blake. Their conclusions were first made public in a paper presented in abstract by Mr. Kohmann, at the Urbana Meeting of the American Chemical Society, April 19, 1916.

The first important problem presented to this group of investigators was the effect of certain mineral salts, such as are commonly found in natural waters, upon the fermentative activity of yeast. The company referred to had been puzzled by the fact that it was found necessary to change both the quantity of yeast and the period of ferment in different localities in order to produce bread of as nearly standard quality as possible, in spite of the fact that the raw materials were identical. Investigation showed that variations in the activity of the yeast were due to the differences in the mineral content of the waters used in making the bread.

However, among the larger number of substances examined it was found that remarkably few exert any important influence upon fermentation in bread. The salts of the mineral acids, such as chlorides, nitrates, nitrites and sulphates exert practically no influence. The carbonates, which are very common in natural waters, are objectionable because they neutralize the acids of the dough and thus interfere with the progress of the fermentation, the carbonates of magnesium and the alkali metals being especially detrimental. The potassium salts were expected to exert a decided influence, especially the phosphates because of their high percentage in the ash of yeast, but were found to have only a very slight effect, that of the phosphates being not noticeable.

Because of their frequent occurrence in water the salts of the alkaline earths were studied in detail, with results of surprising interest, *particularly the calcium salts.*

CONCLUSIONS.

Before going more into detail it is advisable to put before the reader the most important conclusions arrived at during the research. These are five in number:

I. By the use of minute quantities of ammonium and calcium salts and potassium bromate in bread from 50 to 65 per cent of the usual amount of yeast can be saved.

II. Incident to the economy in yeast thus effected there is a saving of about 2 per cent of fermentable carbohydrates, calculated upon the total flour used, due to the greatly diminished consumption of these by the yeast.

III. The proper use of nutrient salts for the yeast gives greater control over the dough and aids in obtaining better and more uniform bread, regardless of locality.

IV. The added salts conserve the inherent qualities of the dough and consequently maintain its stability and strength to a far greater degree than by the old method.

V. The finished loaves are improved in quality, flavor, texture, bloom, and uniformity.

AMMONIUM SALTS.

Experiment proved that like many other acids glutamic acid matures or ages the dough and also increases the gas set free by the yeast. This accelerating effect was observed in bread and likewise in fermenting cane sugar, dextrose, and malt extract. In fermentation of this kind other acids failed to increase the fermentation as did glutamic acid hydrochloride.

So we were led to believe that it was not a matter of acidity but that glutamic acid hydrochloride owes its accelerating effect to this nitrogen content. With this idea in mind, we conducted baking experiments with other nitrogenous substances. Ordinary peptone such as is used for culture media, as already known, accelerates alcoholic fermentation greatly but this substance is expensive and, accordingly, attention was directed toward cheaper materials which would accomplish a similar result. The salts of ammonium were found fully as efficient as peptone.

Early in the research it was observed that the increased fermentation, due to the ammonium sulphate, matured the doughs in a much shorter time. Bread fermented 3½ hours with the use of ammonium sulphate was practically as mature as the control bread in 4½ hours. Obviously then, this salt can be used for the production of bread in a shorter time. On first thought one might infer that this action would be taken advantage of in increasing the output of a bakery; this, however, is not the case. The oven capacity, more than anything else, governs the productive power of a bakery. Although a short fermentation period is highly desirable to the baker shop, there is a limit beyond which it is not safe to go. Unforeseen delays are frequent in the daily operations and since these often occur when the dough is already working, over-fermentation is the result. The shorter the fermentation period, the greater will be the over-fermentation when delay occurs. In our opinion, according to present practices, the fermentation period should not be less than 4½ to 5 hours for hard wheat flours, excepting in special cases in which it is necessary to produce bread in a very short time to

meet rush orders. In general, the increased fermentation due to the addition of ammonium sulphate can best be utilized by reducing the amount of yeast that is ordinarily required.

In small quantities, the volume remains practically unchanged, while it is diminished by 1 g. or more. Alkalis are very detrimental in bread and this, no doubt, explains the inefficiency of ammonium carbonate. Moreover, it was observed that ammonium carbonate imparted an objectionable odor to the bread. The carbonate may be used successfully only when sufficient acid is used to neutralize its alkalinity.

Ammonuium fluoride accelerates the fermentation quite as much as other ammonium salts if used in small quantities; but in larger quantities it retards fermentation to a marked extent.

There was a decided increase in volume and gas production with the increase in the calcium chloride content of the dough. The texture, flavor, and general appearance of the bread were improved as well. The loaf volume was increased considerably more than the gas production, which would indicate that calcium chloride has an effect upon the gluten of the dough as well as upon the yeast. In the light of some experiments conducted by Hardy upon the effect of electrolytes on the strength of wheat flour, this seems highly probable.

It had been previously demonstrated by one of these investigators that the losses in bread-making depend to a large extent upon the amount of fermentation which the dough undergoes. In a normal fermentation the losses were found to be 5.15 per cent, while with the same flour the total losses were only 1.81 per cent when the loaves were placed into pans at once upon mixing. The bread obtained in this way was decidedly poor, as is always the case when it is very much under-fermented, and it was made in this way merely to detect any difference in losses due to fermentation. In self-rising bread the losses were found to be only 0.44 per cent. This difference in the losses of the two types of bread was explained as follows: (1) Yeast produces 1.04 parts of alcohol to every part of carbon dioxide, both of which are largely driven off during the process of baking, while in salt-rising bread there is no alcohol produced. (2) It is necessary to ferment yeast bread in the sponge and dough stages from 5 to 8 hours, and, as it is allowed to rise in loaf form in the pans but one hour or less, only a small part of the total gas produced is actually used in aeration, while salt-rising bread is made into loaves and placed in the pans immediately upon mixing the dough and very little gas is lost. (3) The gases produced by yeast consist of carbon dioxide, while those produced in the salt-rising bacterium consist of about 1/3 carbon dioxide and 2/3 hydrogen, which is only 1/22 as heavy as the former.

The fact that the losses in ordinary bread are dependent upon the amount of fermentation led us to suspect that with the use of yeast stimulants the decomposition of sugar would be less than in a normal dough, because the initial fermentation is much slower and the total gas production is less. With this idea in mind, we made three normal doughs and three with a reduction of 50 per cent in the usual amount of yeast and with 0.5 g. ammonium sulphate and 1.2 g. calcium chloride in 1,000 g. of flour. The gas evolved in the usual time from 50-g. portions of the doughs was collected in Bunsen gas holders and from the total weight of gas produced the quantity of sugar decomposed was calculated, assuming that the carbon dioxide evolved represented 45 per cent of the loss in sugar.

It will be noticed that the consumption in sugar is considerably higher in the control dough than in the one with added salts. The difference represents the saving in sugar that is effected by the use of ammonium and calcium chlorides in bread.

USE OF POTASSIUM BROMATE.

In connection with the use of these salts as yeast nutriments in bread-making, with special reference to the losses, mention will be made briefly of potassium bromate as used in conjunction with them.

In the fermentation of bread, a two-fold object is accomplished, namely, the maturing or aging of the dough and the aeration of the bread. The former is accomplished during the fermentation period, which takes from 4 to 6 hrs. in the best practice, and the latter during the proofing period, which requires from ½ to 1 hr. After the dough is sufficiently matured, or aged, it passes through the dividing and moulding machines, which press out practically all of the gas. Then it is put into pans and allowed to proof, and only the small fraction of the total gas which is produced while the bread is in the pans actually functions in aerating the bread. The effect of the potassium bromate upon the dough is essentially an aging, or maturing effect and is characterized by the exceedingly small quantities required.

Up to a certain point the gas-retaining power of dough and the loaf volume are increased by fermentation; then the dough becomes "rotten," i.e., it no longer retains the gas well and, accordingly, the volume is greatly reduced.

A desirable quantity of potassium bromate—say 0.015 g. per batch of dough containing 600 g. of water—ages the dough so decidedly that 25 or 30 per cent of the usual amount of yeast can be saved without imparting to the bread any of the characteristics of under-fermentation, such as heaviness, dark color and coarseness in texture. In fact, the bromate in these quantities improves the dough with respect to texture even though the yeast is reduced by 25 per cent. This pronounced effect is attributed to the oxidizing power of this salt, for it has been found that by passing oxygen through the dough a similar maturing action is obtained, but of a lesser degree. This is probably due to the condition of the oxygen—in one case we have molecular oxygen and in the other we have nascent oxygen—the nascent oxygen being more powerful than the molecular, and, therefore, having a greater maturing action on the dough. The effectiveness of the nascent oxygen is indeed surprising, for the quantity of the potassium bromate is so small that the total available oxygen is less than 1 cc. per loaf of bread.

When potassium bromate is used in addition to ammonium and calcium salts, it effects a saving in yeast of 25 to 30 per cent of the amount required without it. For instance, when 30 per cent of the usual amount of yeast can be saved with the yeast stimulants, the saving may be increased to 65 per cent with the addition of potassium bromate.

The aging, or maturing effect of potassium bromate upon the dough, without increasing the rate of fermentation or the sugar consumption by the yeast, results in a much greater saving in sugar than that due to the yeast stimulants alone.

Six hours' fermentation is the approximately normal period in the best baking practice, 5 hrs. in the dough state and 1 hr. after the bread is made up into loaves. The range between 5 and 7 hours' fermentation will cover most variations in baking process, due to the requirements of different flours and the type of bread desired. It is clear from the results cited above that the losses increase as the fermentation proceeds and that they are uniformly lower in the new process. The difference in the average losses between the two processes are 2.23, 2.25, and 2.22 per cent in 5, 6 and 7 hours respectively, which is practically a constant. This is to be explained by the fact that after 5 hours the rate of fermentation in the two processes is practically the same. The difference in decomposition of sugar occurs mostly in the initial stages of the fermentation before the nutriments greatly accelerate the activity of the yeast.

It will be noticed that with the normal amount of sugar and added salts the bread is much richer in this substance than the control, while if 2.25 per cent less sugar is used in the batch, the bread is slightly richer in sugar than the control bread.

It is interesting to note that for several hours there is an *increase* in the sugar content of the dough, the old process

reaching a maximum about 2 hours after the dough is set and the new one at about 4 hours. In the light of this fact, it is evident that sugar analyses upon dough cannot serve as an index to sugar consumption by the yeast. The results are of interest, however, in demonstrating the activity of diastatic enzymes; in the new process the sugar content is higher at the end of the fermentation period than at the beginning, showing that the production of sugar is greater than the consumption; in the old process, this does not obtain, as there is nearly 1 per cent less sugar at the end. The difference in the sugar content between the two doughs at the beginning is due to the fact that less sugar is regularly used in the new process.

The economic saving possible by the proper use of nutrient salts, in the advent of a rather general adoption, sums up to surprising figures. Take, for example, the saving in sugar on the average flour production of the State of Kansas—say 20 million barrels or nearly 4 billion pounds. A saving of 2 per cent on this amount is 80 million pounds, and it is mainly sugar that is decomposed and thus lost in bread-making. The ecenomies in the yeast are greater than those in the sugar. Even the moderate use of such a process means a considerable saving to the country, and is a step toward conservation of resources. At the present time, this process is used commercially in the manufacture of more than a million loaves daily.

A further advantage incident to this process of bread-making was observed in the increased stability and stiffness of the dough.

The new process has been used for breads of various types, such as pan breads, Vienna and French breads; also for rye, Graham and whole wheat breads. Likewise, it has been used with spring, winter and Kansas flours, and the different grades of flour, and has been found to be universally applicable.

In connection with the different grades of flour, it should be said that the process cannot be used to give bread the appearance of being made from a higher grade of flour than is actually employed. The improvement in color with the use of the new process is due to the improvement in texture and cannot be regarded as a bleaching process. The grayish color of the lower grades of flour remains in the bread made by the new process just as it does in the usual process. By any process, the color of the crumb is improved by fermentation up to a maximum and in the new process the same changes are noted; much less yeast, however, is required to accomplish the desired results.

The practical application of the new process has met with success, and it is now in operation in a large number of bakeries. A number of these are under the direction of one superintendent, who claims that the process has been of material aid in standardizing the manufacture and maintaining uniformity of the bread in the different localities. As already stated, certain differences were noticed in the bread in a chain of bakeries, although all the raw materials were identical. These have been practically overcome by the new process, which virtually standardizes the water used for the baking purposes. This would be expected, because the required nutriment is supplied by means of these salts used as yeast food, and the addition of further mineral matter, either through the water or otherwise, has less and less exect as the quantities increase. It is a general rule that, in the addition of nutriments or activators in steps, the first portion added has a correspondingly greater effect than the succeeding portions.

For the sake of convenience and accuracy in the use of these salts, they are in practice mixed with flour and salt, so that it requires 8 oz. of the mixture for 60 lbs. of water, or approximately 160 lbs. of bread.

It is but natural to inquire: What becomes of the chemicals during the fermentation and baking of the bread? The purpose of the ammonium salt, as already stated, is to supply the nitrogen required by the yeast and it is of interest to know whether any of it remains in the bread.

Bread No. 1 was made by the new process and it is not as high in ammonia as No. V made without yeast nutriments. None of the breads has an ammonia content that it is at all significant.

The state of combination of calcium in the bread is scarcely subject to question. It has been shown by Teller[3] that the phosphoric acid in flour exceeds by ten times the calcium and it may be safely said that even by the use of the new process, the bread contains several times as much phosphoric acid as is required to combine with the calcium. Under those conditions, the potassium phosphate of the wheat undoubtedly interacts with the calcium sulphate, as it does in wort,[4] in accordance with the following equations:

$$KH_2PO_4 + CaSO_4 = CaHPO_4 + KHSO_4$$
$$2K_2HPO_4 + 3CaSO_4 = Ca_3(PO_4)_2 + K_2SO_4 + 2KHSO_4$$

It is known[5] that the calcium requirements of the body can be supplied by inorganic as well as by milk calcium. Abderhalden[6] has demonstrated taht the complicated organic substances of our foods are replaceable by the simplest structural materials and that these are built up into various tissue substances. It should be mentioned in connection with the use of calcium salts in bread that Rudolph Emmerich and Oscar Loew[6] advocate the use of calcium salts in bread from a purely dietetic standpoint.

The increased lime content of bread by the use of the new process is a very happy coincidence, even though incidental. Unfortunately in modern methods in milling, the greater part of the constituents of wheat is lost to white flour. As indicated by Teller,[7] seven-eighths of the phosphoric acid and eleven-fourteenths of the potash and lime of wheat are found in the stock feed; consequently, a partial restoration of the lime in white bread must be considered highly desirable.

ARTIFICIAL CAMPHOR

THE word camphor was long applied rather indiscriminately to a large number of solid products extracted from natural essences. At present, however, it is conned to the product obtained from the "camphor tree" or *Laurus camphora* which is grown in Japan on a large scale and which is also being planted in Sumatra, Java, and Borneo. Other plants contain this compound, which is often found mixed with borneol. Among such plants are the rosemary, the feverfew, and the sweet marjoram, but it is from the laurel camphor that practically all of the drug used throughout the world is derived, thus giving Japan a virtual monopoly of it.

In recent years the consumption of camphor has considerably increased, while the production has diminished, the result being a rise in the price of the drug and a more intensive cultivation of the tree. But in spite of the new plantations the situation has grown steadily worse. This is, of course, largely due to the fact that the extraction of the camphor entails the total destruction of the tree, since not only the branches but likewise the trunk and the roots are subjected to the action of steam. Unfortunately the trees cannot be utilized until they are from 100 to 150 years old, so that the young plantations set out within the last few years furnish no immediate source of supply. An attempt has been made, but without much success to avoid the destruction of the tree by distilling the camphor from the leaves.

These circumstances have naturally given an impetus to the manufacture of synthetic camphor, which made but little headway so long as the price of natural camphor was low. A study of this subject by a Professor Mailhe appeared in the *Journal des Usines à Gaz* (Paris) of January 20th, 1920. We are indebted to *Le Genie Civil* (Paris) of February 21st, 1920, for the following resumé:

[3] Ark. Agr. Expt. Sta. *Bull.* 42, 70.
[4] Matthews "Manual of Alcoholic Fermentation," pp. 194 and 195.
[5] *Biochem. Z.* 9, 185-207.
[6] Wien. med. Wioch. 62, 177.
[7] Ark. Agr. Expt. Sta. *Bull.* 42.

Perhaps no substance in the entire range of organic chemistry has been the subject of such extensive research as camphor. Partial syntheses of camphor starting with camphoric acid are not difficult to make but they bear no relation to the *industrial* manufacture of artificial camphor.

Camphor, deposited from the oil of camphor obtain by distilling the wood with steam, is a solid substance which melts at 177°C. and boils at 207°C. It polarizes light to the right. Its formula is $C_{10}H_{16}O$. Being of cetonic function its hydrogenation leads to a secondary alcohol, namely, *borneol*. As usual with secondary alcohol the latter undergoes dehydratation, yielding a terpenic carbide, *camphene*. These reactions indicate that there is a very close relation between camphor and camphene, and that this relation is of capital importance in the obtaining of artificial camphor.

Reciprocally, when camphene is subjected to a hydratating action, by means of sulphuric acid, it yields either borneol or the isomer of the latter, iso-borneol, and this, when oxidized, produces camphor.

Evidently then camphene constitutes the primary raw material required in making artificial camphor. However, this terpene exists only in small quantities in certain natural essences, from which it would be difficult to extract it in the pure form. It is now prepared, therefore, by starting with the esence of turpentine which contains "pinene" or turpentene a carbide, which is an isomer of camphene.

The preparation of artificial camphor comprises three steps: 1. the production of the camphene; 2. its transformation into borneol; 3. the passage of the latter into camphor.

1. When gaseous hydrochloric acid reacts upon the pinene contained in the esence of turpentine, it forms a solid hydrochlorate with the liberation of heat. In order to transform this hydrochlorate of pinene into camphene a great many methods have been devised: thus soda and potash in alcoholic solutions produce this reaction; it can also be effected by acetate of lead dissolved in crystallizable acetic acid, by ammonia, by pyridine, and by piperidine.

2. The transformation of camphene into borneol consists in a simple hydratation. The method which appears to be best from the industrial point of view consists in heating in a water bath the camphene together with glacial acetic acid in the presence of a small quantity (about 2 per cent) of sulphuric acid.

3. The transformation of borneol or of iso-borneol into camphor consists in the well known problem of the oxidation or of the dehydrogenation of the secondary alcohol.

The oxidation can be exected by the various agents in ordinary use, such as air or oxygen, in the presence of a catalyzer, ozone, or a solution of permanganate of potash in acetic acid or in acetone.

The catalytic method of the dehydrogenation can likewise be employed with success. In this the vapors of the borneol or iso-borneol are made to pass over finely divided copper, heated to a temperature of from 300 to 330°C. which causes them to split up into hydrogen and camphor. If the operation is properly conducted it is possible to obtain practically pure camphor at once. This method might be employed with advantage in the transformation of certain natural camphors which contain rather large amounts of borneol; and which are upon this account difficult to use and are, therefore, sold at a very low price. By passing the vapor of these mixtures of camphor and borneol over copper heated to the aforesaid temperature, pure camphor would be obtained.

It would seem that this catalytic process, which is much less expensive than the oxidation process as well as easier to handle, must eventually receive the application it merits in the synethesis of camphor.

In brief the manufacture of artificial camphor comprises three series of well known reactions all of which are comparatively easy of application.

Since the raw material consists of turpentine the price of the artificial camphor would be governed by the price of the former. Before the war it was sold in France for 55 francs per 100 kg.; today the price is 600 francs and is steadily going up. The price of hydrochloric acid has likewise gone up. Nevertheless, it seems certain that the manufacture of synthetic camphor can be revived with an expectation of success.

The process of manufacture as described above has undergone certain variations. The most important of these is that which passes directly from the hydrochlorate of pinene to the acetate of bornyle by means of the action of lead acetate.

In this manner one stage of the manufacture is eliminated, since in this reaction, which is made in an acetic medium, the isomerization into camphene and the acetylation of the latter take place at the same time.

Other synthesis also have been effected, and like the foregoing they always lead to a camphor which is inactive with respect to polarized light, to a racemic camphor.

The original article from which this abstract is made contains a number of chemical formulae which we have not deemed it necessary to quote here.—EDITOR.

WHEN TO HEAT WOOD BEFORE GLUING.

WHETHER a hide glue joint will be strengthened or weakened by heating the wood before gluing depends on the size of the joint. It is assumed, of course, that the work is being done in a glue room that is warm and not draughty, and that the wood itself is at room temperature. Under these conditions, if the joint to be made is of small area, heating the wood is unnecessary. In fact it may be detrimental, for the warmth of the wood will keep the glue thin; and, when pressure is applied, too much glue may squeeze out, leaving a starved joint. It is very easy to apply too much pressure to a small area.

In making glue joints of large size (several inches each way), heating the wood before gluing is of distinct advantage. Many experiments at the Forest Products Laboratory, Madison, Wis., have proved that when the wood in large joint work is not heated, the joints develop full strength only in spots. Weak spots and even open joints are too frequently discovered.

Uniform high strength in joints of large size may be secured by heating the wood in a hot box for 10 or 15 minutes at 120 to 130 degrees Fahrenheit just before gluing. The heat from the wood prevents the glue from chilling and keeps it liquid until pressure is applied.

It should be remembered that heating the wood retards the setting of the glue to some extent. In heavy woods, from which the heat escapes slowly, this retarding effect is more marked than in lighter woods. In all species glued cold at the laboratory the time under pressure required to develop full joint strength was less than 8 hours. When heated wood was used at least 10 hours were required to develop full joint strength in mahogany, and more than 12 hours in red oak and maple.

PULP OUTPUT REDUCED BY LONG STORAGE.

How large a loss may be caused by decay in pulp wood through storage was learned in recent observations conducted by the Forest Products Laboratory at a sulphate pulp mill.

Pulp wood which yielded over 3½ tons per digester when used green, after a year's storage yielded only 3 tons. Some which had been stored from 2 to 3 years yielded only 2½ tons per digester. These losses in production, amounting in the latter case to over 25 per cent, occurred without any compensating reduction in operating expenses. Hence the monetary loss was fully equal to what the lost product would have sold for f. o. b. mill.

Such losses can be largely reduced by so operating the wood yard that the wood is used as nearly in rotation as possible, without allowing any to remain in storage as long as one year.

By-Products Coke

Recovering Valuable Products from the Gases Distilled from Coal

By J. F. Springer

ALTHOUGH one of the most abundant elements on earth, carbon is not always easy to obtain, especially if it is desired to have it pure.

Wood charcoal may be taken to represent an effort to produce pure carbon and wood charcoal can doubtless be used as a means of reducing iron ore to pig iron, but it is quite expensive. Bituminous coal contains carbon in two forms. Ordinarily, it also contains a substantial percentage of sulphur. Quite aside from the non-combustible content known as "ash," the carbon is thus associated with other substances. Usually, the important associates are sulphur and hydrogen, the hydrogen occurring in chemical combinations with carbon. Altogether, raw coal is unsuited to the manufacture of pig iron. The blast furnaces require carbon, but sulphur and hydrocarbons are not wanted. Accordingly, it has become customary to separate, as far as is commercially possible, these undesirable substances from the main body of the coal, for the purpose of obtaining a fairly pure carbon. The process employed is coking. By raising the temperature of the coal and at the same time preventing oxygen from reaching it, the hydrocarbons will be driven off in a gaseous form and the sulphur content will be reduced.

There are two principal systems of coking. In the one, no effort is made to save anything but the coke. Valuable hydrocarbons are burnt as they leave the body of coal under treatment, or simply escape into the general atmosphere. In the other system, more or less of the associated material is saved; so that the process yields coke and coal tar and other substances. The simpler system has been developed greatly in the United States and has in fact been in the ascendancy until quite recently. The coke produced is of excellent quality. Probably no other method excells the best American practice in the point of the quality of the coke. The quality relates, in part, to the structural strength of the pieces of coke. It is important in blast furnace practice that the layers or strata of coke in the stack be firm and strong so as not to yield unduly to the superincumbent masses. The type of furnace developed in the United States for the production of coke by the simple method described is known as the bee-hive oven. A typical bee-hive oven consists of a domed structure of brick with two openings, one at the highest point of the dome and the other on one side at the level of the floor. This side opening is for the removal of the coke after it has been made in the interior of the oven, and is temporarily bricked up during actual operation. The top opening provides for charging the oven with a fresh supply of coal and for the exit of gases and flames. The charging is a simple affair, consisting of simply filling the interior up to a specified level. As the floor tilts towards the side opening, the removal of the finished product is not difficult. A few days suffice for a complete cycle of all operations. The simplicity and ease of management and the high quality of coke have together conspired to retain the bee-hive oven in American favor long after Europeans had developed the by-product oven to a high state of efficiency. The by-product oven was not seriously considered in the United States, despite its success abroad, until about 1893. But since that time, it has steadily grown in favor, until in November, 1918, the by-product oven produced 2,500,000 tons of coke. This performance gave it the supremacy for the first time over the bee-hive oven. This crossing of the curves of output may be taken as indicative of a permanent change of relative positions. At the same time, it may turn out that the bee-hive oven will never become obsolete. It satisfies too many requirements of a practical nature.

The by-product oven is, necessarily, a complicated affair, more or less difficult and expensive to build and maintain. Moreover, its operation requires skilled attention. There are various varieties of this type of oven. Some perform one function; some, another, dependent partly on the content of the particular coal coked and partly on the available market. Coke ovens in the Pittsburgh district would perhaps find the by-products of very secondary importance, because of the market for high grade blast furnace coke. A by-product oven plant in the vicinity of New York City would be very differently situated. It would have some choice of the raw material, as the coal in any case would have to be shipped to it. There would be no blast furnace market of any size. This latter case may be illustrated by an actual example.

A large plant has lately been built and equipped on the meadows near Jersey City. The plant produces: (1) coke for foundries, blast furnaces, cupolas, steam plants, domestic stoves; (2) gas for consumption in homes and business offices; (3) tar, from which such products as creosote oil, various other oils, pitch, lampblack and dyestuff raw materials may be obtained; (4) ammonium sulphate, which finds service as a fertilizer material, as a refrigerating agent, etc.; (5) benzol, which may be used as a dilutent of gasoline for motor use, etc.; naphthalene, useful in the manufacture of dyes and moth balls. Here we have quite an array of by-products, some of them quite valuable. Coal containing high relative amounts of hydrocarbons is employed as the raw material. It comes from the Pittsburgh and Clearfield districts. The plant is on the Hackensack River, one mile from Newark Bay. The Erie, the Lackawanna and the Pennsylvania railroads are all within easy reach. Coal may be shipped to the plant by all-rail routes or by a route carrying it first to a tidewater terminal port in New York harbor by rail and thence by boat or barge to the water-front of the plant. A certain amount of economy is possible by utilizing incoming coal cars and barges as outgoing coke carriers.

SEALING THE DOORS OF A BY-PRODUCT COKE OVEN BEFORE TURNING ON THE HEAT

This plant is a very considerable one, consisting of 165 ovens arranged in a single row, divided into three sections of 55 ovens each. Each section is termed a battery and is operated as a unit. The length of time required for coking is around 16½ hours, which is in marked contrast to the time required by the bee-hive oven. It has been estimated that, with 165 ovens operating on a 16½-hour cycle, the daily output is 2,200 tons of coke, 16,500,000 cubic feet of surplus gas having a thermal value of 610 b.t.u. per cubic foot, 75,000 pounds of

DUMPING THE QUENCHED COKE

ammonium sulphate, 24,000 gallons of tar and 10,000 gallons of light oil. All this comes from a daily input of 3,000 tons of coal. As to economy, it is claimed that the tar and ammonia pay for the operation and maintenance.

Just across the river from the plant are located plants of the Public Service Gas Company and of the Public Service Electric Company. The big coking plant receives operating current from the one (submarine cables being used for transmission), and supplies gas holders of the other with illuminating gas. A tunnel beneath the river provides a crossing for the pipe lines carrying gas.

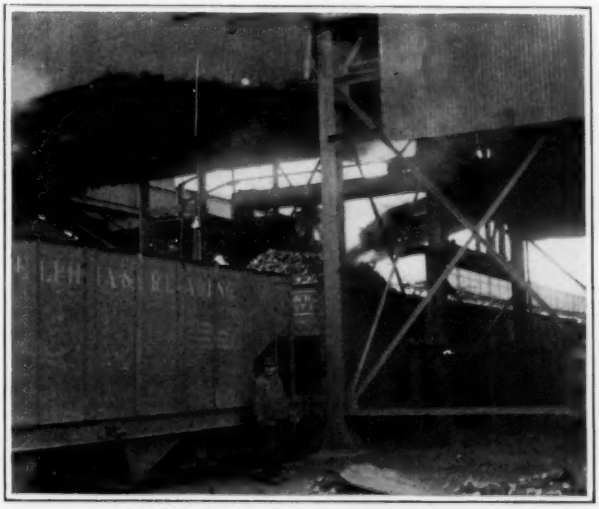
It may readily be imagined that it amounts to a real problem to keep this great plant supplied with its daily quota of coal. While coal comes in by water and rail, as already intimated, it is necessary nevertheless to have a stock on hand to tide the plant over inequalities and actual stoppages of delivery. There is, consequently, a stock-yard of 150,000 tons capacity. Ordinarily, the barges coming in with coal are able to continue service all through the winter; but, in 1917-1918, the weather became so severe that no barge was able to bring in coal for a period of seven weeks, although there were 7-foot tides at intervals. It is well, then, that entire dependence is not put upon the supply by barge, and that the railroad and the storage yard are also available.

Coal in the storage yard is piled normally to a height of 30 feet. But 40 feet is permissible without serious interference with the mechanical arrangements for reclaiming the coal. The wharf at which the coal barges discharge is 800 feet long. Here, as many as 24 barges may be docked at a time. But, this is not to be understood as 24 1,500-ton barges. The unloading tower which deals with the incoming coal barges is equipped with a big clam shell bucket competent to grab 5 tons of coal at a time. This bucket is electrically operated and is able to unload 600 tons of coal per hour. The bucket itself weighs 7 tons, is 14 feet high and is when open 15 feet wide. This monster bucket delivers to a big hopper and the hopper in turn delivers, through a suitable regulating gate, to a system of pan conveyors. The conveyor pans are 36 inches wide, as are also the belts to which they deliver and which traverse a big system of interlocking conveyors, located between the tower and the mixer building. At a suitable point in the conveyor arrangements the coke is weighed and the weight recorded by a belt scale. From data obtained from such records, the rate of stocking has been ascertained to be some 450 tons per hour.

The stock yard is 1,200 feet long and is filled by means of two horizontal conveyor belts. The one belt carries coal 450 feet, when it trips to the stocking and reclaiming bridge or to the second stock conveyor or else by-passes coal to two incline belts which supply a breaker. The second conveyor covers the remaining 750 feet, is reversible and handles coal and coke.

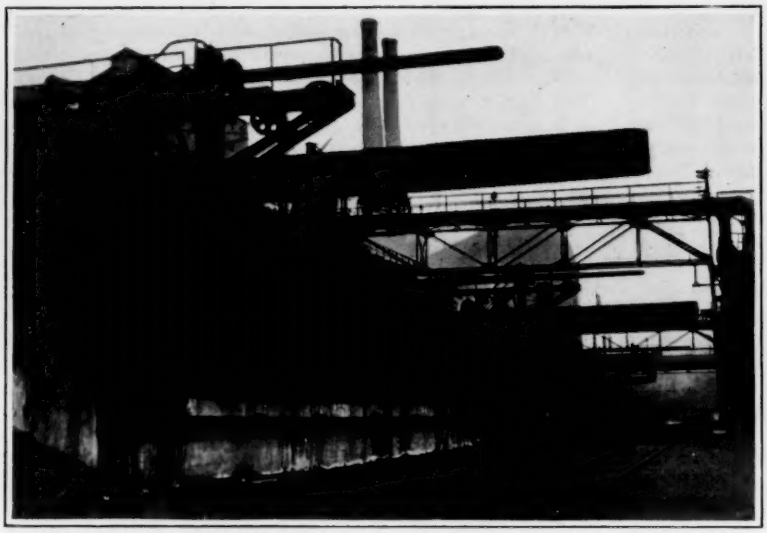
The bridge is a big affair which extends across the shorter dimensions of the yard and which may be shifted along the 1,200-foot length. In fact, this bridge may be skewed 20 feet either way, but is automatically prevented from being thrown further out of normal position. The bridge is, at one end, equipped with a stocking boom which extends over one side of the storage space towards the center. A grab bucket is operated to transfer coal along the 215 feet of bridge not covered by the stocking boom and may be used to reclaim to the stocking belts. The unloading of railroad cars is provided for by means of two hoppers which receive from the cars and deliver to a pan conveyor and inclined belt.

The coal as it comes from the mines is, not all of it, quite ready for the ovens. Coal delivered at the top of the crusher and mixer house passes over a screen which separates the fine from the lump. The lump coal is delivered to a breaker. This is an interesting device which consists in part of a revolvable inclined cylindrical screen. This is 12 feet in diameter and 17 feet long and is provided interiorally with shelves which serve to carry the coal up the incline. From the screen the coal drops 10 feet upon steel plow points. Coal that is more or less broken up has, as it moves along inside the screen, opportunity to drop through 1½-inch perforations. There are two short belts which carry fines from the breaker to any one of three mixer storage bins.

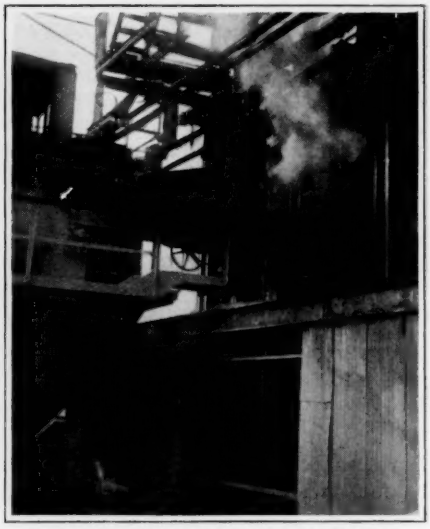


LOADING THE COKE INTO THE CARS

The coal is mixed and then beaten to very small sizes in two hammer mills. The first consideration in a plant like this concerns the chemical composition and coking quality of the coals; but the second has to do with the mixing and the degree or degrees of fineness. The hammers are of high carbon steel and at their tips have a linear speed of 2¼ miles per minute. There is a screen arc plate whose raising and lowering affects the size of the crushed coal. So much for the mechanical equipment employed in getting the coal from storage, barge or cars to the ovens.



THE "PUSHERS" WHICH TRAVEL ACROSS THE FACE OF A BATTERY OF OVENS AND PUSH THE COKE OUT OF THE INDIVIDUAL OVENS



PUSHING THE COKE INTO A QUENCHER CAR ON THE OPPOSITE SIDE OF OVEN

Leaving the ovens, the coke passes over 13 coke conveyors which make use of a total of 4,250 feet of belting. These conveyors, if run at capacity, demand 27,500 kw.-hrs. of current per month.

The coal, mixed and crushed, is delivered in weighed quantities to the ovens. That is, a big 15-ton specially designed larry car conveys the coal in its four conical hoppers to four charging holes in the tops of the ovens and there discharges through its quick-dumping gates. The lids belonging to the holes are removed prior to the arrival of the car. The coal runs down into the oven, whereupon a long steel bar is operated to level off the piles. After the leveling bar has done its work, the small door through which it was operated is closed, as are also the four lids of the charging holes. Just as soon as the fourth lid goes into place, a certain valve is opened and the way is left clear for the outward passage of gas, *via* a 13-inch pipe, to a big steel collecting main. There are two types of colecting main—the lean and the rich mains. During the earlier half of the coking period, the gas made has a high calorific average, the thermal content being put at 610 B.t.u. per cubic foot at standard atmospheric pressure. This is the rich gas and is collected by the rich main. During the latter half of the operating period, the average thermal content drops to, say, 525 B.t.u. This gas is passed into the lean main. A certain amount of this gas is required to provide for the heating of the ovens themselves.

Control of the temperatures of the ovens permits a schedule to be made of the cycle of operations. Thus, the whole period may be set to occupy a time which may be varied within not very wide limits around 16 hours. At the termination of the pre-determined operating period, the valve admitting to the lean main is closed, and the four charging lids are pushed to one side. Also, the big brick-lined doors at the two ends of the oven are taken off. One side of the oven is the "coke side." There is, on the coke side, a steel guide or rack, through which the new coke is shoved by a heavy ram operated by power. The ram pushes the hot coke into a steel quencher car. The mechanical device which pushes out the new coke includes other functions in its duties. It operates on tracks which parallel the batteries of ovens and in addition to pushing, levels the coal and takes off the doors. The car which receives the coke is of steel, has a sloping bottom and is equipped with side dumping doors. The dumping is accomplished by a compressed-air device, supplied with air from a compressor located on the electric locomotive whose business it is to haul the quencher car. When the car load of fresh coke is hauled over to the quenching station, a big shower-device is operated and the nine tons of red hot coke is in one-half minute cooled to a point where the remaining heat is but little more than enough to drive off the surface moisture, the quenched coke retaining about 3 per cent moisture. The car is next hauled to a place of discharge, where the load is dumped upon a sloping surface. From this last, it may be drawn off as desired and carried by conveyor or belt to the screens.

It will be understood that the coke thus produced is the main thing. It is, in fact, the fixed carbon of the raw coal. The remaining carbon content is all in the by-products, which are non-solids. With the bee-hive oven, the coke is the whole of what remains at the close of operations, except of course the ash. In the present type of by-product oven, the gas, ammonia and other volatile substances are driven off by the heat of the oven. They pass through long steel pipes to points outside the by-product building where primary coolers operate to reduce the temperatures. From the coolers, the by-products pass to the exhausters which are inside the building. From the exhausters, the gas under pressure goes through extractors which remove the tar, through reheaters and through saturators. All these operations are carried out inside the building. The gas is next sent outside to certain direct coolers, benzol washers and purifiers. It is now ready for a gas-holder, whose capacity is 30,000 cubic feet. The gas has now been cleaned and purified and has received a certain amount of enrichment. In short, it is ready for the consumer. Booster engines drive it through mains laid in the sub-sqeous tunnel underneath the river and into storage holders of the Public Service Gas Company.

The exhausters mentioned above draw the gaseous substances from the ovens, causing them to pass through the primary coolers which operate by the passage of cold water through tubes. The temperature of the gas is thus brought down automatically to 66°F. This one cooling operation suffices to separate most of the tar, ammonia liquor, moisture and naphthalene. As the gas, relieved now of a great part of its load, passes through the exhausters themselves, the temperature goes up some 12 or 13 degrees. The special tar extractors next operate to separate out the residue of tar. Preparatory to passage through the saturators, the gas has its temperature raised to 140°. The heating is done by means of steam heated tubes. In the lead-lined saturators, the gas is caused to pass through very dilute sulphuric acid. The saturator operates, through a chemical reaction between ammonia in the gas and the sulphuric acid, to extract all but a small percentage of the total ammonia. The ammonia as recovered

is ammonium sulphate in crystal form. The white crystals are washed in water to remove the free acid, after which operation they are dried in centrifugal hydro-extractors. Ammonium sulphate is an important refrigerating agent used in certain ice-making and refrigerating systems.

The plant includes a special laboratory building devoted to experimental investigation and routine chemical tests. A second laboratory is connected with the benzol plant and takes care of the special testing required in connection with benzol. At the benzol plant is recovered the light oil forming part of the by-products. This oil is made up of benzol, toluol, etc. Both benzol and toluol may be used as diluents of gasoline used for driving motors. Whether it is profitable to use them thus, depends naturally on relative prices. Benzol and toluol have also importance in dye manufacture. Toluol is the basis for the manufacture of TNT (trinitrotoluol) the violent explosive. The broad method of extracting the complex light oil is of interest. The gas from the saturators is "washed" with an oil adapted to absorb the light oil, and the mixture is then treated in a suitable still, which operates to drive off the light oil. The absorbent employed is a paraffine oil having a high boiling point. Naturally, the high boiling point is necessary, so that the whole of the light oil may pass off as vapor without carrying absorbent oil with it.

BROWNED ALUMINUM.

TO PROTECT aluminum and aluminum alloys from corrosion, L. von Grotthuss has tried the experiment of browning the metal electrolytically. The aluminum is suspended in an electrolyte consisting of a sulfur compound of molybdenum and zinc is used for the anode. The cell is maintained at a temperature of 60° to 65°C. The aluminum is soon covered with a dark brown coating. The metal may be bent or rolled without cracking the coating. A piece of aluminum thus coated was immersed in a salt solution for two months without showing the slightest trace of corrosion.—Abstracted from *Metall und Erz*, Jan. 22, 1920.

FUEL VALUE OF WOOD.

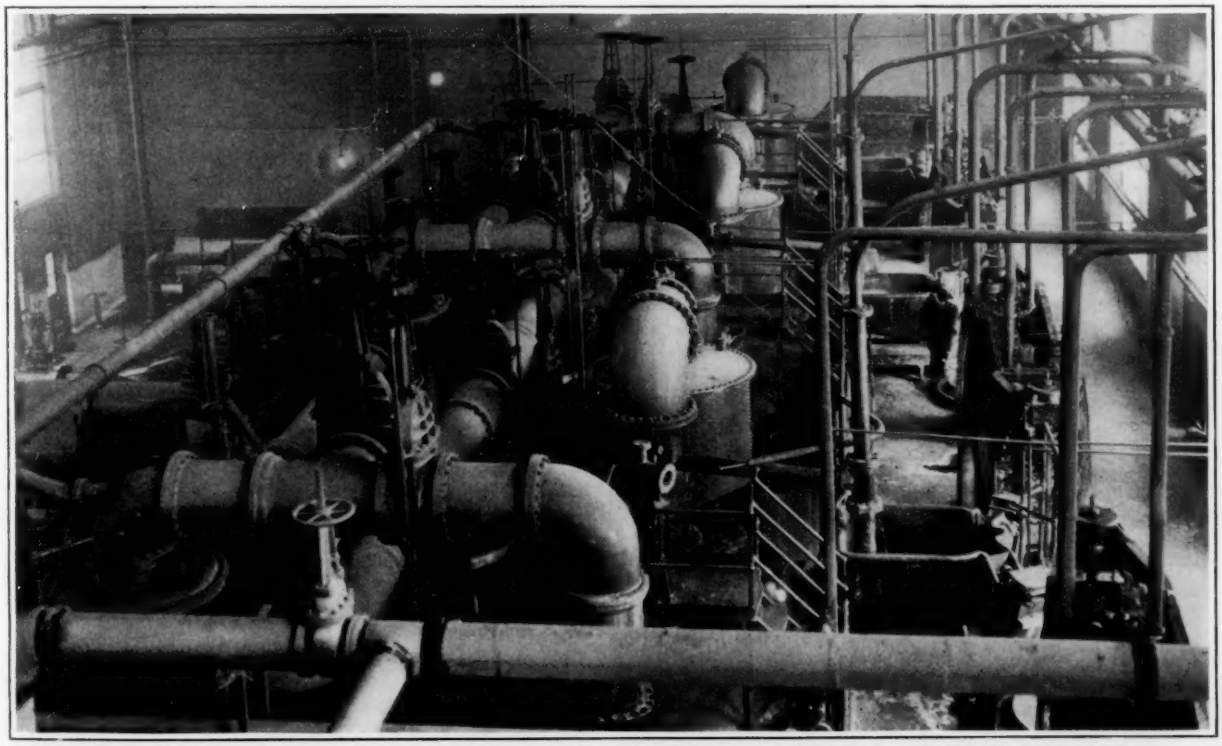
Two pounds of dry wood of any non-resinous species have about as much heating value as a pound of good coal. Speaking in tons and cords, a ton of coal may be taken as the equivalent in heating value of 1 cord of heavy wood, 1½ cords of medium weight wood, or 2 cords of light wood.

The following table is an approximation of the number of cords of seasoned wood of various kinds needed to give the same amount of heat as a ton of coal, on the basis of 80 cubic feet of wood, with a moisture content of 15-20 per cent to the cord:

1 cord	hickory, ash, oak, elm, beech, locust, birch, longleaf pine, hard maple, cherry	= 1 ton coal
1½ cords	short leaf pine, Douglas fir, western hemlock, sycamore, red gum, soft maple	= 1 ton coal
2 cords	cedar, cypress, redwood, basswood, poplar, spruce, catalpa, white pine	= 1 ton coal

Resin gives twice as much heat as wood, weight for weight. Hence such woods as the pines and firs have more heating power per ton than non-resinous woods. The resinous woods in the table are considered as having an average amount of resin (15 per cent).

The fuel value of wood depends in many cases not alone upon its heating power, but also upon such qualities as easy ignition, rapid burning, freedom from smoke, and uniform heat. As a rule soft woods burn more readily than hard woods, and light woods more readily than heavy woods. The pines give a quicker, hotter fire and are consumed in a shorter time than birch; whereas birch gives a more intense flame than oak. On the other hand, oak gives a very steady heat and is one of the most satisfactory fuels.



THE BY-PRODUCT PLANT INTO WHICH THE GASES FROM THE OVENS ARE CONDUCTED AND THERE DISTILLED TO RECOVER THE VARIOUS BY-PRODUCTS

Some Phases of the Fuel Problem*

Relative Advantages of Oil and Powdered Coal

By George A. Orrok

IN the early days of central-station development it was maintained that the cost of fuel was such a small percentage of the average sales price of electricity to a customer that it hardly paid to go to the expense of condensing engines, as the saving incurred was not warranted by the increased fixed charges on the installation. In those ancient days the fuel, while possibly the largest single item, did not exceed 10 per cent of the average sales price to the consumer, today our average prices are so low and the progress in economical power generation has been such that the fuel cost, still the largest single item, is 25 per cent of the average sales price to the consumer. And the fuel cost is still mounting. The cost of mining, increasing values of coal lands, restrictions of output, increases in the freight rates and cost of handling have more than trebled the price of coal to the Eastern companies and these increases have more than balanced the economies shown by the labor designs and arrangements of central-station apparatus.

It had been considered by most engineering authorities that the fuel problem for our larger companies had been definitely settled and along fundamental lines. The steam generator may be considered as perfected, especially as efficiencies as high as 80 per cent to 82 per cent are attainable under test with all of the types of boiler at present used in central-station practice. These efficiencies are not likely to be seriously exceeded since the necessary radiation and chimney losses are rarely below 12 to 14 per cent, and the problem at the present time is how close the average boiler-room efficiency, over a year, can be brought to the possible test efficiency.

With well-designed stations and careful operating, good coal and a reasonable load factor, the average yearly boiler-room efficiency has been maintained from 74 to 76 per cent in a number of the better plants. For a plant using around 300,000 tons of coal per year each additional per cent of efficiency means a saving of about 4,000 tons of fuel per year, or $20,000 at the present New York price of coal. Very few plants are provided with instruments for obtaining these facts from day to day, but the yearly use of coal is obtainable with sufficient accuracy from the coal bills or railroad weights, and all plants can afford water meters on the feed-water lines, although few have them. We may say that the poorer plants show a yearly boiler-room efficiency running from 50 to 65 per cent, and the better plants an efficiency from 65 to 75 per cent, beyond which it is extremely difficult to go on account of banking losses, combustible in the ash, excess air and cleaning losses.

Poor coal is responsible for large efficiency losses. The accompanying table, showing the effect of increasing percentages of ash in the coal on boiler efficiency, has been prepared from averages of a large number of tests on anthracite, bituminous and Western coals. These averages vary but show as a general rule that 20 per cent of ash content cuts down the efficiency 15 to 20 per cent; 40 per cent of ash reduces the efficiency by about 70 per cent, and with 50 per cent of ash it is practically impossible to maintain combustion, to say nothing of evaporating water or making steam. Iron oxide, with or without sulphur, accentuates this condition by producing a fusible ash which slags the grates and chokes the draft. The presence of combined water in most of the Western coals and lignites reduces the efficiency in a marked degree, but not to such extent as the presence of ash. Combustion is possible at a greatly reduced efficiency under exceptional conditions, even with as high as 50 per cent of water.

*Abstract by the *Electrical World* of a paper presented before the Association of Edison Illuminating Companies, New London, Conn., Sept. 15 to 18.

ADVANTAGE IN PULVERIZED FUEL.

Apparently the main advantage in the use of pulverized fuel is the fact that the surface of the solid particles of fuel has been augmented more than 200 times, so that ignition and combustion are nearly instantaneous and the mixture of air and combustible is much more nearly perfect, very little excess air being needed. The chief difficulty is in the feeding devices and so proportioning the combustion chamber and air inlet that the mixture is complete. Sufficient heat must be present at the ignition point to ignite every particle, and this temperature varies from about 600 deg. Fahr. with high volatile coals to 1,000 deg. to 1,200 deg. Fahr. for anthracite.

AVERAGE LOSS IN EFFICIENCY DUE TO ASH IN COAL

Per Can of Ash	Loss of Efficiency — Anthracite Coal	Bituminous Coal	Western Coal
10	12	10	6
20	23	20	18
30	45	40	32
40	70	75	98
50	100	100	...

When these precautions are taken and the air is preheated, furnace temperatures up to 3,000 deg. Fahr. are easy of attainment, smokeless combustion is assured, and practically all the combustible is consumed. The combustion chamber must be proportioned for the maximum condition, in which case the efficiency will be nearly constant over a wide range.

Most of the ash will be deposited in the combustion chamber as dust with refractory ash or as slag if its fusing point is low. Apparently there is very little loss of efficiency with an increase of the ash content, as tests with high-ash coals show the same efficiency as with low-ash content. A properly designed combustion chamber limiting the gas velocities in the neighborhood of the firebrick surfaces will, it is claimed, overcome the excessive cutting and slagging of the brickwork so prevalent in all of the earlier experiments, and this proceeding will greatly diminish the amount of ash and slag particles carried into the tube banks and uptakes.

There remains the fact that the coal must be pulverized and therefore must be freed from moisture. Combined water to the extent of 5 to 7 per cent is not serious, but free water over 1 per cent usually makes trouble in the pulverizing and handling. Outside of radiation and stock losses and the loss from excess air, this is the only loss large enough to be troublesome.

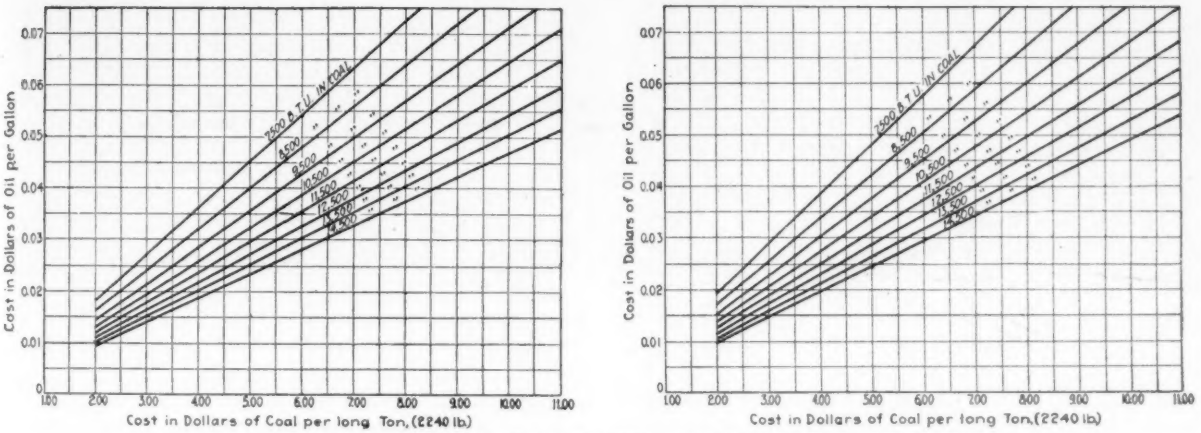
The advantages incident to a powdered-fuel installation may now be summed up:

1. Ability to use all classes of coal with equal (or nearly equal) efficiency.
2. Reasonably smokeless combustion.
3. Absence of loss of combustible in the ash.

Against these may be placed these disadvantages:

1. The cost of drying and pulverizing the fuel.
2. Higher and possibly irregular temperatures with attendant disintegration of the firebrick furnace lining.

Where good coal is used and yearly station boiler efficiencies of from 74 to 76 per cent are obtainable, it may be possible to increase the yearly efficiency by 3 per cent. With a 65 per cent yearly efficiency at least 10 per cent better results should be obtained. Where cheaper grades of coal are available even more considerable savings are possible.


Cost in Dollars of Oil per Gallon
Cost in Dollars of Coal per long Ton,(2240 lb)
Cost in Dollars of Oil per Gallon
Cost in Dollars of Coal per long Ton,(2240 lb)

FIGS. 1 AND 2—COMPARATIVE COSTS OF COAL AND OIL IN HEAT EQUIVALENTS

Fig. 1 assumes coal burned at 70 per cent efficiency and oil at 74 per cent efficiency: 18,500 B.t.u. per pound in oil and that oil of 18 Baumé = 7.877 lb. per gallon. Fig. 2 assumes coal burned at 70 per cent efficiency and oil at 77 per cent efficiency; other assumptions the same. Saving of labor and in banking fires is not included.

This 3 per cent, or 60,000 a year, under our former supposition, will be offset by the cost of drying and pulverizing 288,000 tons of coal per year, which for no saving would mean 21 cents per ton as the cost of pulverizing. Where the yearly efficiency is 65 per cent and a 10 per cent saving could be made, 75 cents could be paid for pulverizing. For a plant using 1,000 tons per day the cost of pulverizing could not be far from 40 per cent per ton, leaving a net saving of over $80,000 per year. In general the pulverizing cost runs from 40 cents to 50 cents for the largest plants up to $1.50 or higher in small installations.

It will be readily seen that the poorer the plant in design and operating practice, the larger will be the savings from the use of pulverized coal as fuel, given the same coal conditions.

A late paper gives a list of powdered-coal installations for the generation of steam—eighteen in all; installed boiler horse-power, 24,000; average size, 1,333 h-p.; largest installation, Puget Sound Light & Power Company, 10 B. & W. boilers, 4,100 h-p.; next largest Milwaukee Electric Railway & Light Company, five 468 h-p. Edge Moor boilers, 2,340 h-p. These are the only central-station installations listed. Another company lists six installations of which one is under construction. The total boiler horse-power in this case is 22,000. The largest plant will be the River Rouge plant of the Ford Motor Company at Detroit, where four 2,645-horse-power Ladd boilers are being installed. Besides these there are numerous small installations not listed.

It was only a few years ago that oil as fuel began to be used in a few locations where coal freights were high and oil freights low. The newer developments of the Mexican fields and the steadily increasing price of coal now bring this subject to our attention.

The coal production in the United States is not far from 600,000,000 tons per year, of which about 40,000,000 tons is used in the making of steam by central stations for the generation of electric power.

The figures for oil production, including Mexico, are about 400,000,000 barrels, of which a little less than half may be available for power purposes, including gas-engine fuels. Excluding the portion used for marine purposes, possibly 40,000,000 barrels, mostly topped oil, will be available for steam purposes at a reasonable price. This would correspond roughly to 10,000,000 tons of coal. About 10,000,000 barrels of fuel oil per year are used for central-station purpose today.

Most authorities assume that oil firing will give a boiler efficiency 10 per cent better than coal firing. Indeed, long run efficiencies of 80 per cent have been reported and test efficiency of over 82 per cent is common. Taking oil as having a heating value of 18,500 B.t.u. per pound, and a coal a value of 13,500 B.t.u. per pound, oil at 3 cents per gallon is equivalent to $5.65 coal. If only 4 per cent better efficiency is maintained, then 3-cent oil is equivalent to $5.90 coal. I have not considered the saving in labor, banking coal, ash handling, etc.

On this basis I have calculated the two charts in Fig. 1 and 2, which show the corresponding price of oil and coal. No difficulty need be apprehended in the change-over. Indeed, oil burning is frequently successful in old-fashioned low settings; the grates are covered with firebrick and the burner inserted in the firedoor. It is generally agreed that steam atomizing is more efficient than air atomizing or mechanical atomizing, but mechanical atomizing is largely used in marine work and in the smaller land installations. With steam atomizing the use of steam may be as large as 15 per cent of the boiler evaporation, but the best results are obtained when careful regulation restricts the use of steam to 1½ to 2½ per cent of the boiler output.

The type of burner, while important, has much less effect on the efficiency of combustion than the size and design of the combustion space and the arrangements for the introducing and regulating of the air necessary for combustion.

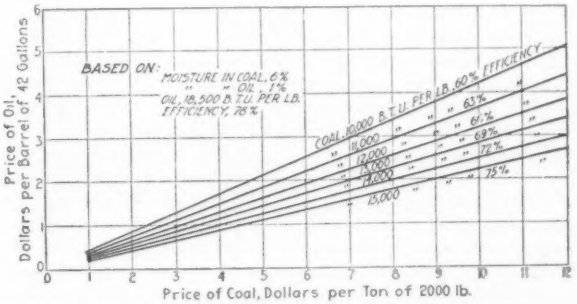

BASED ON: MOISTURE IN COAL, 6%
" " OIL, 1%
OIL, 18,500 B.T.U. PER LB.
EFFICIENCY, 78%
COAL, 10,000 B.T.U. PER LB. 60% EFFICIENCY
" 11,000 " " " 63% "
" 12,000 " " " 66% "
" 13,000 " " " 72% "
" 14,000 " " " 75% "
" 15,000 " " "
Price of Oil, Dollars per Barrel of 42 Gallons
Price of Coal, Dollars per Ton of 2000 lb.

FIG. 3—RELATION OF PRICE OF COAL TO PRICE OF OIL IN HEAT EQUIVALENTS

Oil storage and firing devices, while costly in a new installation, will cost less than coal bunkers, coal-handling machinery, stokers and forced-draft apparatus. The cost of operating the oil storage and feeding devices depends in a large measure on the mean annual temperature since fuel oil is extremely viscous and must be warmed sufficiently to be pumped and then preheated to secure good ignition before injection into the furnace. As the flash point of fuel oil is always above 150 deg. Fahr., the item of fire risk is very low, all of the so-called "wild hydrocarbons" having been removed in the topping process.

We may now state the advantages of oil firing:

1. An almost perfect control of firing and combustion conditions, insuring high and maintained boiler efficiency over a wide range.
2. Extreme flexibility.
3. Low labor cost both in the boiler room and bunkers.
4. Stability of costs due to the conditions of production and the increasing demand for the products of the topping process.

The disadvantages are:

1. Limited applicability to favorable localities.
2. The relatively high cost of installation, which does not decrease with size of plant.

LIQUID OXYGEN AS AN EXPLOSIVE.*

By Albert G. Wolf.

For many years it has been known that liquid air or liquid oxygen mixed with some highly carbonaceous substance makes a powerful explosive when detonated. During the war some experimental work was done in America along this line, but, owing to the difficulty in handling, in part, and largely to insufficient pressure by "Mother Necessity," no great measure of success was attained, and the method was dropped as being of no commercial or practical value. In Germany, however, conditions were entirely different. There, according to the publications of the German Oxhydric Joint Stock Co., the method was brought to a fairly high degree of perfection.

The liquid oxygen, or, as used, a liquid consisting of 98 per cent oxygen, is made from air. The air is first washed free from carbon dioxide. Then it is liquefied by the expansion process, multi-stage compressors and ammonia refrigerating machines being used. After making the liquid air, the oxygen content is raised by taking advantage of the lower boiling point of liquid nitrogen. The liquid nitrogen, evaporating first, leaves a higher percentage of oxygen in the liquid residue, and by carrying out this step in a specially designed apparatus in which advantage can be taken of the extremely low temperature created by the evaporation of the liquid nitrogen, a fairly high degree of efficiency is obtained.

In order to form an explosive mixture, a highly carbonaceous material with the power of absorbing liquid is necessary in addition to the liquid oxygen. This material should preferably be shaped in the form of dynamite sticks for convenience in handling and loading. It is claimed that best results are obtained from cartridges made of cork charcoal and a binder of paraffin. The binder may also be any one of the lighter petroleum products. Kieselguhr (diatomaceous earth) with a binder of paraffin may also be used. In that case the paraffin alone furnishes the carbon, and the explosive is not as powerful as when the charcoal cartridge is used. A good ratio is said to be 60 parts of kieselguhr to 40 parts of binder.

In using this explosive, the liquid oxygen must be carried to the working place in tightly closed thermos bottles, in order to avoid loss by evaporation. The liquid oxygen is then poured out into double-walled vessels, and the cartridges are placed in the liquid to soak. The cartridges must be capable of absorbing sufficient excess of oxygen to insure the presence at the time of detonating of enough to burn all the carbon to carbon dioxide and all the hydrogen to water. Otherwise the deadly carbon monoxide gas will be formed on exploding the charge.

The cartridges are saturated when they sink. They are then hastily removed from the bath, placed in the drill holes, fitted with electric blasting caps, tamping placed before them, and exploded. Not much time must elapse between the removal of the cartridges from the bath and the detonation, the permissible time varying from three to fifteen minutes, depending on the nature and size of the cartridge, because of the rapid evaporation of the liquid oxygen. For this same reason the diameter of the cartridge should not be less than 30 mm. The drill holes should be slightly larger to allow the oxygen vapor to escape while loading, otherwise the cartridges might be prematurely pushed out of the hole.

Though electric firing gives the best results, it is possible to use fuse and cap, or fuse alone. With the fuse, however, there is the danger of prematurely igniting the oxygen vapor and of getting an incomplete combustion. Fuse, of course, should not be used where there is the possibility of fire damp being present.

Experiments have shown, according to the claims of German manufacturers, that to get the same force of explosion, the relative weights of various explosives must be used:

Cork charcoal, paraffin and liquid oxygen	58
Kieselguhr, paraffin and liquid oxygen	115
Blasting gelatin	86.2

The advantages claimed for this method of blasting are primarily economy, safety, and greater strength of explosion. Economy is claimed because each mine can operate its own little liquid oxygen plant for not much more than the cost of operating a compressor plant, making it necessary to buy only the cartridges of carbon. There is safety in handling and storage because the separate ingredients are not explosive. There is absolutely no danger from misfires, because in fifteen to thirty minutes all the liquid oxygen in a drill hole evaporates; and, it is claimed, with the lower-strength cartridges, there is no danger of igniting fire damp. There are also the advantages that low temperature has no effect on the explosive, and, where proper precautions are observed, no poisonous gases are formed.

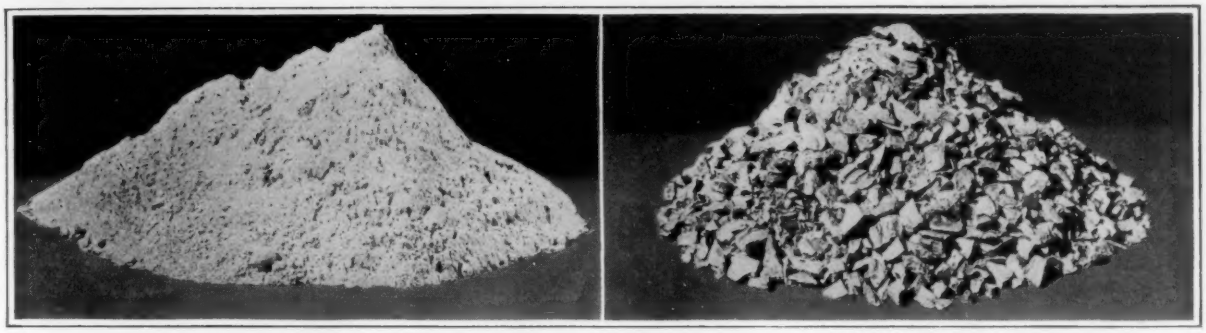
To the average mine operator or miner, the disadvantages of this method far outweigh the advantages. There is the trouble of carrying the liquid oxygen containers and immersion vessels, in addition to the cartridges, to and from the working faces, the loss of a good percentage of these vessels and the resulting cost, the loss of a large percentage of the liquid oxygen, and the operation of the liquid-oxygen plant. Then there is the danger from hasty and improper immersion, with its resulting loss in efficiency of the explosive and the formation of poisonous gas in the mine. In large stopes, the complication that would arise from the use of liquid oxygen would be almost insurmountable.

*Reprinted from the *Engineering and Mining Journal*, Feb. 4, 1920.

MAKING THE ROOF SAVE HEAT.

Two of the main functions of a good roof are the keeping in of heat in the winter and the keeping out of heat in the summer, the former being by far the most important, in this climate, at any rate. It is usually supposed that this power of keeping heat in or out as the case may be is dependent upon the quality of the roofing, as a good conductor or a bad conductor of heat. Some highly interesting studies made by Mr. W. M. Thornton of the National Physical Laboratory in England, with regard to roof materials, prove, however, that the brightness or dullness of the roof is also an important factor. Mr. Thornton found, in fact, that loss of heat through the roof depended more upon the nature of the surface and the degree in which it radiates heat than on the conductibility of the materials. The same grade of galvanized iron roofing which is an excellent heat insulator when polished loses 50 per cent more heat when it is blackened inside and more than five times as much when it is blackened on both surfaces.

One of the best of roofing materials proved to be pine covered with tar paper; tiles are also excellent, but are, of course, much heavier, as well as more expensive. Fibro-cement was likewise found to be very good, and is improved by painting with aluminum. A specially admirable roof when one wishes to have a house covering which is both light and warm is one made of corrugated fibro-cement covered on the underside with a continuous layer of tar paper, the cushion of air enclosed between the two layers adding materially to the warmth of the roof.



CALCIUM MOLYBDATE

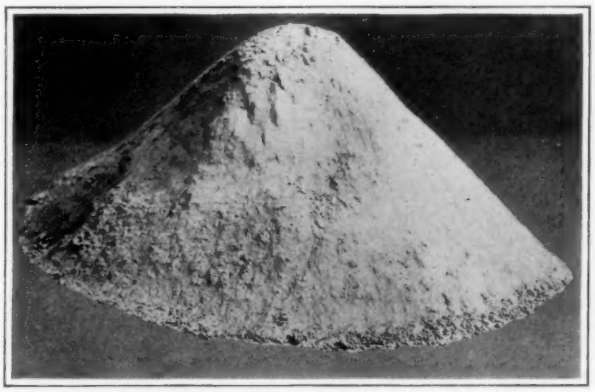
FERRO-MOLYBDENUM

Qualities of the Molybdenum Steels*

New Alloy That Came Into Use, During the War, for Aircraft Crankshafts, Gun Shields, and Similar Purposes

IN the course of the war there were introduced into practical use a series of new alloy steels which bid fair to become of great value to the automotive industry. Reference is to molybdenum steels, which are generally of the nature of ternary or quarternary alloys. During the war molybdenum steel was used for the fighting turrets of tanks, for gun shields, helmets, aircraft engine crankshafts and connecting rods, and for other parts requiring great strength combined with low weight.

Among the chief advantages claimed for alloy steels containing molybdenum are that it does not require the same care in heat treatment as other steels, as practically the same physical properties are obtained for a range of more than 200 degrees Fahrenheit in the quenching temperature. Molybdenum improves the static test results of various kinds of alloy steel to which it is added, such as chrome steel, chrome vanadium steel, etc. Moreover, molybdenum steel is said to be easier to machine than other alloy steels and the saving in machining cost easily pays for the cost of the alloying element, it is claimed.



A PILE OF MOLYBDENUM CONCENTRATES

THE ELEMENT MOLYBDENUM.

Molybdenum, one of the metallic elements, has been known for about 150 years. It derives its name from the word molybdæna, by which most minerals resembling lead in appearance were known in the 18th century. It is produced chiefly from the sulphite molybdenite (MoS_2) which is a mineral very similar in appearance to graphite. Molybdenite and other molybdenum-bearing ores are widely distributed throughout the world.

The metal molybdenum resembles platinum in general appearance, although it is darker and possesses a peculiar lustre. Its atomic weight is 96; its specific gravity is 9; its specific heat 0.07, and it melts at about 4600 deg. F. Despite its very high melting point, it alloys readily with iron, the ferromolybdenum having a melting point of approximately 2650 deg. F. Metallic molybdenum exhibits a high degree of resistance to the corrosive action of most acids and chemicals.

ORE DEPOSITS IN COLORADO.

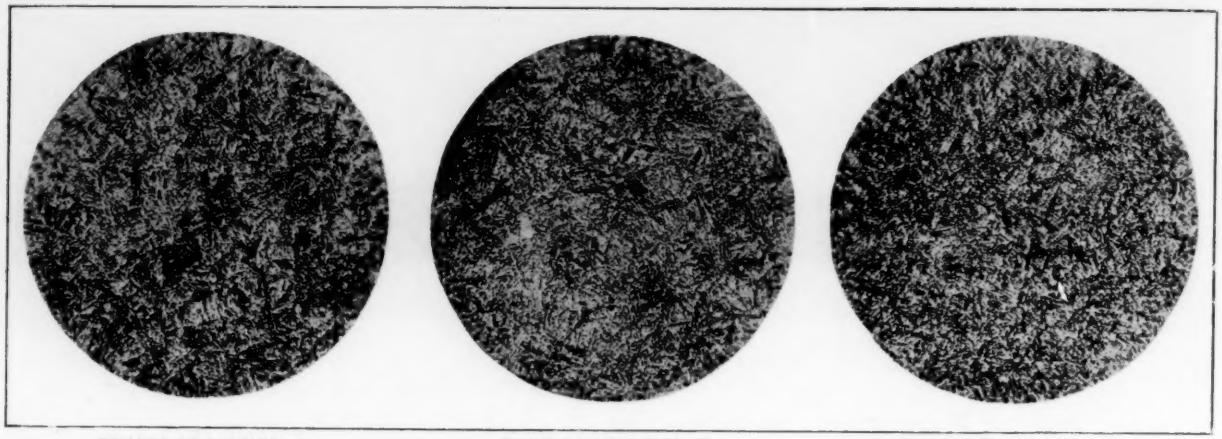
While its ores are widely distributed, up to a few years ago molybdenum was considered a semi-precious metal, no deposits of any great magnitude having been discovered. A few years ago a company acquired possession of a deposit of molybdenum sulphide at Climax, Col., northeast of Leadville. At that point an ore reserve has been developed which at present has a capacity of 1,000 tons a day, and it is claimed that the ore which has already been developed insures steady operation of the plant for more than thirty years. The entire ore body has not yet been developed.

The ore is broken, delivered to the mill by aerial tramway, ground and concentrated by oil flotation to form 60 to 70 per cent molybdenum sulphide. The concentrates are then converted into ferromolybdenum or calcium molybdate, in either of which forms the metal can be introduced into steel. The ferromolybdenum is produced in two grades, both containing from 50 to 60 per cent metallic molybdenum. The regular grade is guaranteed to contain a maximum of 2 per cent carbon, and the special grade, of 0.5 per cent. In the great majority of instances, the former can be used. The calcium molybdate contains about 42 per cent metallic molybdenum, the rest being lime. There is said to be no free carbon or sulphur in this compound.

INCREASES TOUGHNESS OF STEELS.

One of the claims made for molybdenum steel is in regard to toughness, and this claim is based on "reduction of area" figures obtained in physical tests. Molybdenum steels of any given elastic limit and elongation are characterized by an extraordinarily high reduction of area. Reduction of area is also said to be an index of machineability. For machine parts requiring a high elastic limit, the cheapest method of manufacture consists in finish-machining the parts directly from the heat-treated forging. This eliminates warping and scaling

*Reprinted from *Automotive Industries*, January 29, 1920.



DRAWN AT 350 DEG. F. DRAWN AT 700 DEG. F. DRAWN AT 1100 DEG. F.

TRANSVERSE SECTIONS OF TYPE I-A ALLOY MAGNIFIED 300 DIAMETERS

of semi-machined parts. Furthermore, material submitted to the machine shop is completed without the loss of time and the confusion resulting from intermediate heat treatments. All testing is finished before machine labor is expended upon parts which might have to be rejected later, such rejection involving the loss not only of material but also of labor and tools.

HIGH DRAWING TEMPERATURES.

One peculiarity of molybdenum steel is that it will acquire desirable physical properties when drawn at a comparatively high temperature. The physical changes accompanying the usual heat treatment are well known. When a piece of steel is heated beyond a certain critical temperature it undergoes a physical transformation. If it is allowed to cool slowly from the highest temperature reached, the process reverses itself and the material returns to its original state. On the other hand, if the steel is cooled rapidly, as by quenching, the physical changes which took place on heating, cannot reverse themselves, and the material then remains in a state of unstable equilibrium. When the quenched steel has been reheated or drawn, physical reactions, which were retarded by quenching are allowed to take place to an extent proportional to the reheating temperature, and the molecular instability induced by quenching is somewhat modified.

It results from the above that the higher the drawing temperature after quenching, the nearer the approach to a state of molecular equilibrium, and consequently the greater the resistance of the material to any subsequent molecular change. One form of molecular change in steel is that known as fatigue, which is the result of continued mechanical vibration. It is argued that the higher the drawing temperature for given physical properties, the greater the resistance to dynamic stress or to fatigue. Higher drawing temperatures mean ease in furnace regulation and manipulation, and, furthermore, the nearer the approach to the point of molecular equilibrium, the less sensitive is the steel to temperature variations. In other words, wider limits may be allowed in commercial heat treating practice. It need hardly be emphasized that the wider these limits the less chance there is for failure of the treatment and for the necessity of retreatment.

RELATED TO CHROMIUM.

In the periodic system of elements, molybdenum is classed as a member of the chrome family. In some respects its effect upon steel is similar to that of chromium. It has been found, however, that by combining these two alloying elements, properties can be developed in steel which are unobtainable by the use of any single element.

Accompanying this article are a number of photo micrographs which bring out the effect of different amounts of molybdenum on the structure of quenched and drawn chrome molybdenum steel. They also indicate the uniformity of the steel when drawn at different temperatures. All of the steels of which photo micrographs are shown were quenched in oil from 1600 deg. F., and drawn as indicated. Steels of two different specifications were made use of in producing these photo micrographs; all those bearing the number I contain 0.25 per cent of carbon, 0.48 per cent of manganese, 0.18 per cent of silicon, 0.95 per cent of chromium and 0.73 per cent of molybdenum, while all those bearing the number II contain 0.32 per cent of carbon, 0.49 per cent of manganese, 0.10 per cent of silicon, 0.90 per cent of chromium and 0.40 per cent of molybdenum.

CHROME-MOLYBDENUM STEEL.

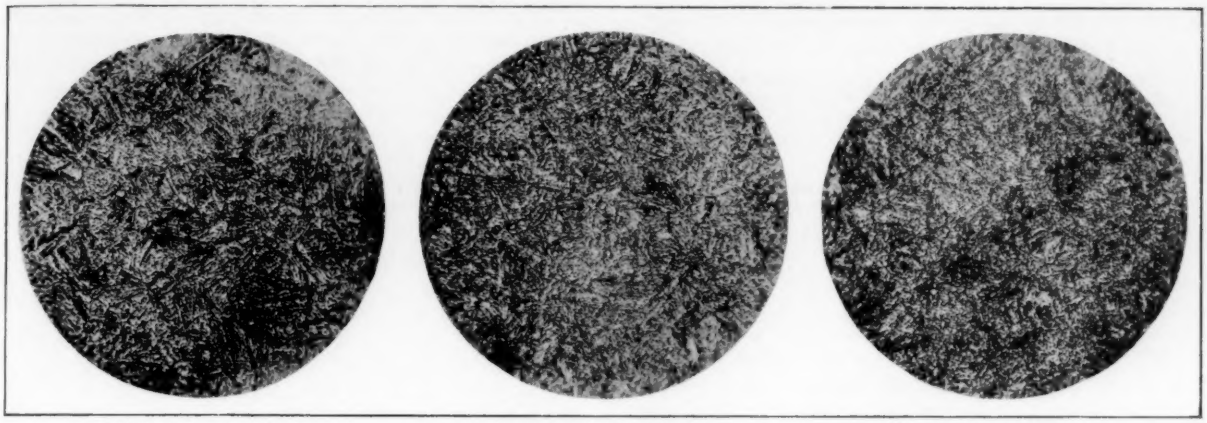
If chromium be added to a carbon steel or a nickel steel, and the steel subsequently be heat-treated, their elastic limit and tensile strength are increased (up to a certain point) with the quantity of chromium. However, it is impossible practically to take advantage of the high elastic limits resulting from the addition of a considerable amount of chromium, because it is accompanied by brittleness (as measured by low elongation and reduction of area). For regular commercial purposes the limit of chromium is in the neighborhood of 1 per cent, although for several purposes up to 1½ per cent of chromium is sometimes added. If steel with a normal per cent of chromium is taken and molybdenum is then added, the elastic limit is increased more than it would be by a further equal addition of chromium, and—what is of the greatest importance—the brittleness is decreased at the same time.

Thus a chrome carbon steel, containing 0.27 per cent carbon, 0.64 per cent manganese and 0.99 per cent chromium, when properly heat-treated, showed the following physical properties: Elastic limit, 130,000 pounds; tensile strength, 139,000 pounds; elongation, 16.5 per cent; reduction of area (1 in. round), 58 per cent. Upon the introduction of a moderate amount of molybdenum, so as to obtain a steel containing 0.26 per cent of carbon, 0.64 per cent of manganese, 0.77 per cent of chromium and 0.31 per cent of molybdenum, the following physical properties were obtained: Elastic limit, 143,000 pounds; tensile strength, 151,000 pounds; elongation, 18.5 per cent; reduction of area of 1 in. round specimen, 53 per cent.

While the results obtained from the chromium steel are of a high order, to obtain them in regular commercial practice requires very careful supervision of the heat treatment and of the chemical composition of the steel. It is claimed for molybdenum that it not only intensifies the effect of the chromium itself, but has an independent effect on those properties of the steel which are undesirably affected by the use of chromium alone.

CHROME NICKEL MOLYBDENUM STEEL.

The effect of adding molybdenum to chrome nickel steel is well brought out by the following analysis of a Liberty motor crankshaft. The chrome nickel steel originally used for this



DRAWN AT 700 DEG. F. DRAWN AT 1100 DEG. F. DRAWN AT 1300 DEG. F.

TRANSVERSE SECTIONS OF TYPE II-A ALLOY MAGNIFIED 300 DIAMETERS

crankshaft contained from 0.35 to 0.45 per cent of carbon, 0.50 to 0.80 per cent of manganese, 0.10 to 0.20 per cent of silicon, 0.70 to 0.90 per cent of chromium and 1.75 to 2.75 per cent of nickel. This material showed an elastic limit of 129,760 pounds, a tensile strength of 144,460 pounds, an elongation of 17.2 per cent, a reduction of area of 53.7 per cent, an Izod impact value of 46 ft.-lb., and a Brinell hardness of 307.

Another grade of chrome nickel steel used in connection with aircraft production during the war had the following chemical composition: 0.28 to 0.37 per cent of carbon, 0.30 to 0.70 per cent of manganese, 0.10 to 0.25 per cent of silicon, 0.65 to 1.36 per cent of chromium and 3.04 to 3.50 per cent of nickel. This showed the following physical properties: Elastic limit, 167,000 pounds; tensile strength, 135,200 pounds; elongation, 19.6 per cent; reduction of area, 51.7 per cent; Izod impact value, 61 ft.-lb.; Brinell hardness, 370.

Liberty aircraft engine crankshafts were made from chrome nickel molybdenum steel made by the United Alloy Steel Corporation of Canton, Ohio. This steel contained from 0.236 to 0.305 per cent of carbon, 0.50 to 0.69 per cent of manganese, 0.09 to 0.15 per cent of silicon, 0.74 to 0.98 per cent of chromium, 2.85 to 3.05 per cent of nickel and 0.32 to 0.54 per cent of molybdenum. This steel tested as follows: Elastic limit, 130,000 pounds; tensile strength, 142,000 pounds; elongation, 20.5 per cent; reduction of area, 65 per cent; Izod impact value, 67 ft.-lb.; Brinell hardness, 303.

STEEL SUITED FOR AUTOMOBILE PARTS.

For such automobile parts as crankshafts, connecting rods, steering knuckles, steering levers, front axles, etc., grade MO-2 steel is frequently used. Tests on specimens from approximately 4,000 finished crankshafts made from this grade, at the plant of a large American automobile manufacturer, showed the following average compositions and physical properties: Carbon, 0.25 to 0.33 per cent; manganese, 0.71 to 0.76 per cent; chromium, 0.45 to 1.04 per cent; silicon, 0.11 to 0.22 per cent; molybdenum, 0.32 to 0.46 per cent. The physical properties averaged as follows: Elastic limit, 131,700 pounds; tensile strength, 149,900 pounds; elongation, 17.7 per cent; reduction of area, 61.8 per cent; Brinell hardness, 304. Chrome vanadium steels used for crankshafts under the same operating and test conditions at the same plant showed approximately the same elongation, reduction of area and Brinell hardness, but the elastic limit averaged only 113,000 pounds, and the tensile strength 127,600 pounds. This same steel is used for cold drawn automobile axle shafts, and in this form shows an elastic limit of 145,000 to 156,000 pounds per square inch, and a tensile strength of 164,000 to 171,000 pounds per square inch. As an indication of the extraordinary toughness of molybdenum steel, the following results from a class steel containing from 0.75 to 1 per cent of molybdenum are interesting. The test was made on a 1⅛-inch round specimen 24 inches long. It showed a fiber strength at the elastic limit of 50,100 pounds, and a fiber stress at the breaking point of 107,000 pounds. The twist degree per inch, before failure, was 258.

These results were obtained from test pieces taken from the finished crankshaft, and they should be read in the light of the knowledge that it is possible to draw the steel at from 1150 to 1200 deg. F. The high drawing temperature removes quenching and forging strains, thus eliminating the need for straightening operations during machining. It is stated that the shafts machined exceptionally well.

NICKEL-MOLYBDENUM STEELS.

The addition of molybdenum to nickel steel containing no chromium results in markedly increasing the elastic limit and the toughness and ductility for a given elastic limit, as measured by a reduction of area and elongation. This effect is particularly pronounced when the steel is drawn at higher temperature. Nickel molybdenum steels can be readily machined, and can be heat-treated without detriment to their physical properties within a wide temperature range; they are exceptionally homogeneous and free from fiber and flakes. As an instance of the homogeneity of the steel and its freedom from defects, it is mentioned that in the manufacture of the Renault baby tanks, over 99½ per cent of the nickel molybdenum steel parts passed all stages, including ballistic tests, while 76 per cent was the maximum in the case of the straight nickel steel.

It is claimed for molybdenum steels that they are less liable to warp in the course of manufacture, owing to the depth-hardening effect of molybdenum, which, among other things, permits the quenching of irregular sections with a minimum of warping. This peculiarity of the steel is of considerable commercial value in connection with oil-hardened parts, as straightening operations during manufacture are eliminated.

The following two tables show that molybdenum steel can be heat-treated at widely varying temperatures without detriment to its physical properties:

TENSILE TEST OF CHROME-MOLYBDENUM STEEL, MO-2

Analysis Range

Carbon	Manganese	Chromium	Silicon	Molybdenum
.23 to .30	.50 to .80	.80 to 1.10	.10 to .20	.25 to .40

Physical Properties

(1¼ inch round)

Water Quench	Elastic Limit	Tensile Strength	Elongation Per Cent	Red. of Area Per Cent
1500° F.	149,600	162,900	16.0	57.2
1550° F.	151,000	163,400	16.5	57.3
1600° F.	148,800	163,600	17.0	57.3
1650° F.	148,500	161,400	16.5	58.9
1700° F.	149,500	162,400	16.5	56.8

All drawn at 1000° F.

TENSILE TEST OF CHROME-NICKEL MOLYBDENUM STEEL, LM

Analysis Range

Carbon	Manganese	Nickel	Chromium	Molybdenum
.25 to .35	.50 to .80	2.75 to 3.25	.70 to 1.00	.30 to .50

Physical Properties

(1 inch round)

Oil Quench	Elastic Limit	Tensile Strength	Elongation Per Cent	Red. of Area Per Cent
1400° F.	175,200	185,000	16.0	52.5
1450° F.	179,300	187,400	15.5	51.5
1500° F.	171,200	182,700	16.5	55.1
1550° F.	174,200	185,100	16.0	52.8
1600° F.	172,700	183,500	15.0	51.7

All drawn at 1000° F.

It will be seen from these tables that in spite of the wide range in drawing temperatures, there was only a slight variation in the physical properties.

What is referred to as the depth-hardening effect of molybdenum is illustrated by Brinell hardness readings taken along diagonal lines of 3½-inch square sections of molybdenum and chrome vanadium steel respectively. The maximum hardness in each case was 293, while the minimum hardness, at the center of the section was 262 in the case of chrome molybdenum steel, and 235 in the case of the chrome vanadium steel.

FIVE TYPES OF MOLYBDENUM STEEL.

Molybdenum steels are made in five types, as follows:

Type MO, chrome molybdenum.
Type MS, chrome molybdenum, higher carbon.
Type LM, chrome nickel molybdenum.
Type NM, nickel molybdenum.
Type VM, chrome-vanadium molybdenum.

The type MO is made in three molybdenum ranges, as follows: Class A, 0.25-0.40 per cent molybdenum; class B, 0.50-0.75 per cent molybdenum; class C, 0.75-1.00 per cent molybdenum. It has been found, however, that the class A meets practically all commercial requirements and is usually specified.

The MS type of chrome molybdenum steel is used for chassis springs and for heavy gears. The carbon content is made as low as 0.35 per cent for forgings and as high as 0.6 per cent for rivet sets, etc. Besides, the steel contains 0.60-0.90 per cent of manganese, 0.10-0.20 of silicon, 0.80 to 1.10 per cent of chromium and 0.25 to 0.40 per cent of molybdenum. Physical properties obtained in the spring steel are as follows: Elastic limit, 180,000-210,000 pounds; tensile strength, 200,000-230,000 pounds; elongation, 12 to 15 per cent; reduction of area, 37 to 45 per cent.

ADDITION OF MOLYBDENUM TO STEEL.

There has been an impression, based upon past practice, that molybdenum, when introduced into steel, will volatilize or oxidize out of the bath. This is denied by molybdenum producers who assert that the metal can be introduced into steel as easily as nickel, and with recoveries practically as good. Molybdenum, in the form of a ferro-alloy, may be introduced into the steel by any of the customary methods. Recent developments have shown that it may also be introduced in the form of calcium molybdate. With ferro-molybdenum, the alloy may be introduced in the bath just after the charge becomes plastic, and a little before the melt becomes level, when it may be thrown in, casks and all. It should not be added with the charge because of possible loss on the furnace bottom. It may also be added just after the final additions of ferro-manganese and ferro-chrome, that is, a few minutes before the furnace is tapped.

Instead of adding the alloy to the bath, it may be added in the ladle, in which case it is advisable first to melt it, and then pour it into the molten stream after the furnace is tapped. This latter method was the first one to be employed during the war, but it was later replaced by the previously described method. When calcium molybdate is used, it is added in the early stages of the heat, preferably a little before the melt becomes level. Whatever the type of furnace, it is well to remember that the molybdate must come in direct contact with the molten iron, and must therefore be added (in the basic furnace) before the lime begins to come up. Shipped in sheet iron drums or in sacks, the molybdate is added, containers and all.

Researches at High Temperatures and Pressures*

Investigation Into the Internal Conditions of the Earth

By Sir Charles A. Parsons, K.C.B., F.R.S.

JUST ten years ago in this room Sir Richard Threlfall discussed the effects of temperature and pressure on various substances, and commenced by referring to a suggestion I made in 1904 to sink a bore-hole twelve miles deep in the earth with the object of exploring the region beneath us, about which so little is known. Last summer at Bournemouth I ventured again to direct attention to the desirability of such an exploration in the interests of science generally, and to the possibility that it might ultimately lead to some developments of practical importance and utility.

Ten years ago no experiments had been made on the behavior of rocks under the conditions existing at great depths below the surface of the ground; but, prompted by my suggestion in 1904, and after some subsequent correspondence in regard to the possibility of the rock crushing in and closing the shaft, Prof. Frank D. Adams, of McGill University, Montreal, commenced experiments on the strength of rocks to resist the closing up of cavities under the conditions prevailing at great depths below the surface. He published the account of these experiments in the *Journal of Geology* for February, 1912.

Adam's method was to place a block of granite or limestone in a tightly fitting cylinder of nickel-steel, which was shrunk lightly around the block to ensure perfect fitting and support; hard steel rams actuated by a hydraulic press were arranged to exert a known pressure against the ends of the block. Two small holes were previously drilled in the specimen, one axial in the center and one traverse, the diameter of the holes being 0.05 in., or one-tenth the diameter of the specimen. The temperature of the container and specimen was maintained at any desired point up to the softening point of steel. In some experiments no heat was applied, while in others the temperature was raised to that estimated to exist at the depth below the surface of the earth corresponding to this pressure.

When no heat was applied the holes in the granite showed no alteration under a pressure equivalent to thirty miles deep, and in the case of limestone the specimen supported one-half of this pressure without alteration. Adams then raised the temperature of the container and specimen. When granite was heated to 550°C., a temperature corresponding to eleven miles below the surface, it stood a pressure equivalent to fifteen miles, and might have stood more but that the container became weakened by the heat. Limestone begins to decompose at a temperature of 450°C., but even at this temperature it withstood a pressure corresponding to ten miles.

*Discourse delivered at the Royal Institution on Friday, January 23. Reprinted from *Nature* Feb. 19 and 26, 1920.

Adams concludes that small cavities in granite will not close in under the conditions of pressure and temperature at eleven miles below the surface, however long a time is allowed to lapse, and that the cavities may persist to much greater depths, but the softening of the steel of the container precluded the carrying of his experiments to still higher temperatures and pressures.

So far as they go, these experiments are reassuring as to the permanence and safety of a pit shaft twelve miles deep sunk through granite, but it would be more satisfactory to experiment on a larger specimen than one only ½ in. in diameter as used by Adams and to heat the specimen electrically when submerged in graphite while keeping the container cold, the temperature being indicated by a thermo-couple in the specimen. This could be carried out in a nickel-steel container like that shown in Fig. 2.

In this connection P. W. Bridgeman in 1911 submerged a sealed glass tube containing a cavity under an external hydrostatic pressure of 24,000 atmospheres (corresponding to a depth in the earth of fifty-six miles) for three hours, and the cavity showed no change in size or form. It, however, appears that temperature will probably place a limit to the depth that could be reached before the closing in of the shaft commences to occur, for Judd, Milne, and Mallet agree in the view that the deepest origin of earthquakes is between thirty and fifty miles. This would seem to indicate that at greater depths than thirty miles the temperature and pressure are such that changes of form take place by plastic deformation, and not by sudden slips or the formation of faults, which are the chief cause of earthquakes. Again, Oldham states that beyond twenty miles deep seismic waves which are transmitted by compression and distortional vibrations change in character in this respect that though the compressional waves are only slightly affected in velocity, on the other hand the distortional waves are reduced to one-half their velocity. This would seem to imply that the modulus of elasticity in shear has, at twenty miles depth, owing to the rise of temperature, fallen to one-half, and it seems probable that the rock also is weakening in its resistance to shear; in fact, that the rock is becoming more plastic, and that cavities would probably close up at twenty miles below the surface.

The greatest depth to which a shaft has as yet been sunk is only about 1 1/5 miles. The deepest single-stage shaft on the Rand is that of the Hercules East Rand Proprietary Mine. It is 4,500 ft. vertically, and rectangular in section. The deepest shaft in the world is that of Morro Velho, Brazil. The bottom is 6,400 ft. vertically below the surface, and it has been sunk, and is worked, in stages, two of which are about 1,200 ft. vertical. The deepest shaft designed on the Rand is by the City Deep Co. It is 7,000 ft. vertically, is circular of 20 ft. diameter, and is to be worked in two stages of 3,500 ft. each. The most rapid sinking record was made at the Crown Mines No. 15 Shaft, where 310 ft. were sunk in a month; the shaft is circular, and of 20 ft. in diameter.

There are several interesting departures from ordinary mining practice necessary. The haulage is arranged in stages of about half a mile, principally in order to economize the weight of rope and also the power for winding. In countries where the atmosphere is dry the sides of the shaft are cooled by sprinkling water upon them, which by evaporation cools the rock. It is, however, possible to augment the effect by artificially drying and cooling the air before passing it down the mine.

When still greater depths of shaft are in contemplation further methods of cooling in addition to these would probably be found necessary; for instance, the carrying of the heat upwards by means of brine circulated in a closed ring formed of steel pipes with a rising and descending column. Though the columns might be carried the whole depth of twelve miles, the hydraulic pressure at the bottom would be about 12 tons per square inch, and entail very costly pipes of great strength to resist the pressure. A cheaper plan would be to work in stages, each ring covering a stage of from two to three miles of the shaft, the heat being transferred from the top of one brine ring to the bottom of the ring above by surface-heat exchangers and refrigerating machinery to neutralize the heat drop on transfer. These may be called heat pumps, and would be driven electrically.

As the depth of the shaft increases, the pressure of the air upon the miners will be about doubled for every three miles, but what is more serious is the increase in temperature of the air itself caused by the adiabatic compression due to gravity, by which it will be raised about 100°F. For these reasons it will be necessary to place airtight partitions across the shaft at every mile or two, and to carry on the ventilation through these by means of a pump to deliver the foul air upwards and an expander to allow the fresh air to descend. These two machines would be linked together, and the difference in their power supplied by an electric motor. (This method has been often used with water, and is equally applicable to air.)

At each partition heat exchangers and refrigerating machinery similar to those used for the brine would be placed. Another and preferable plan would be to place numerous heat exchangers between the ascending columns of air to transfer heat from one to the other. The air would, in this case, not itself act as a conveyor of heat to the surface, for which the brine columns would be depended upon, but it would enable airlocks every three miles to suffice. A further alternative and very simple method would be to convey liquid air from the surface, and allow it to escape at the part of the shaft requiring cooling. It would ensure good ventilation.

When sinking the deeper portions of the shaft, shields would probably be necessary to protect the miners from the splintering of the rock which is caused by the intense compressive stress, which splits off scales from the surface, sometimes with considerable violence.

In 1904 the estimate of the time required to sink twelve miles was eighty years, and was based on the records of that time. With improved machinery and methods the records have been so much lowered that an estimate of thirty years seems now to be reasonable.

Threlfall traced the gradual evolution of the theory of the effects of temperature and pressure on the allotropic forms of various substances. He described his apparatus and experiments designed to melt graphite under high pressure, his inference then being that under pressures up to 100 tons per square inch carbon does not follow the same law as many other substances and does not crystalize as diamond on cooling.

An interesting discovery was made by Bridgeman in 1911 when studying the compressibility of mercury. He found that it had a remarkable power of penterating steel containers, a power not possessed by oil or water, which caused them to burst at much lower pressures than when they were charged with oil or water. The phenomenon he attributed to the act that mercury has the power of dissolving small percentages of iron, and will amalgamate with it when the surfaces are absolutely free from oxide.

In 1912 Bridgeman published his remarkable researches on water under pressures up to 20,000 atmospheres. He found that there are four allotropic forms of ice besides ordinary ice, which are found under various conditions of pressure and temperature with determinate regions of stability. All these forms except ordinary ice are more dense than water; one is remarkable as existing from a temperature of -18°C. under a pressure of 4500 atmospheres up to a temperature of 67° C. under a pressure of 20,000 atmospheres.

Recently a pressure of from 200 to 1,000 atmospheres at a temperature between 50° and 700° C. has been applied to compel hydrogen to combine with nitrogen to form ammonia on a great commercial scale, a catalyst being necessary to promote the combination and to establish the equilibrium between the gases and their product. This action is reversible as

regards temperature and pressure. On the other hand, iron just molten is an energetic catalyst in the transformation of diamond into graphite, but, contrary to expectations, as we shall see, no amount of pressure that has yet been applied appears to have caused a reversal of this action.

More than thirty years ago, having suitable apparatus at hand, I made a few experiments to try the effect of high pressures and temperatures on carbon, compounds of carbon, and some other substances.

The apparatus consisted of an 80-ton press, under which suitable containers were placed, and a turbo-generator of 24 kilowatts output at 80 volts provided the current. It had been discovered by Cheesborough that the carbon filaments or incandescent lamps became very hard and resilient when heated in a hydrocarbon atmosphere of about 4 mm. absolute pressure, and I was anxious to try what would be the result if a rod of carbon were electrically heated when submerged in a liquid hydrocarbon under high pressure. Benzine, kerosene, treacle, chloride, and bisulphide of carbon were tested under a pressure of 2200 atmospheres, or about 15 tons per square inch. The results were not successful in producing a hard coating to the rod or in increasing materially its density and hardness except in the case of tetrachloride of carbon, which slightly consolidated and hardened it; on the contrary, the carbon deposited from the liquids always appeared as soft amorphous carbon like soot. These experiments were extended by substituting, instead of the liquids mentioned, silica, alumina, and other substances and increasing the pressure to 30 tons per square inch. When the current density was sufficiently increased the rod was converted to soft graphite. Moissan in 1903 expressed the view that iron in a pasty condition was the matrix of the diamond, and that great pressure was the determining factor, which compelled a minute fraction of the carbon present to appear as diamond; he further referred to the probability that carbon is liquefied when under a pressure sufficient to prevent its volatilization, and that from the liquid state it may pass into the crystalline form on cooling. Crookes, in his lecture delivered before the British Association at Kimberly in 1905, emphasised the same view as to the probability of the crystallisation of carbon directly from the molten state on cooling.

Though my original experiments in 1888 were not favorable to these views, it nevertheless seemed desirable to carry the investigations up to the greatest possible pressures attainable. Experiments were, consequently, resumed in 1907 with a new equipment, which consisted of a 200-ton hydraulic press and a storage battery of 360 kilowatts output. The battery can be coupled for 2, 4, 8, 16, or 48 volts as required, and the mains and the main switch can carry currents up to 80,000 amperes to the hydraulic press, which is placed by itself in a small, strong house partly below ground, with walls of 2 ft. thickness reinforced with steel bars; the door is of steel 3 in. thick, and the roof is of light galvanised iron. The container under the press is further enclosed by 2 in. thick telescoping steel rings, raised into position by steel ropes and counter-weights. These precautions, as experience showed, were necessary, as several violent explosions occurred which cracked the steel rings and blew off the roof. A charge of iron and carbon, when confined and raised to a high temperature, may be very violent if suddenly released by the melting of the pole-pieces; also some endothermic compounds have been formed which swelled the container and allowed the contents to escape.

My experiments confirmed the conclusion at which Threlfall had independently arrived: that under pressures up to 100 tons per square inch and very intense heating by electrical current, graphite is not materially changed. But modifications in the experiments were made and other methods adopted, as will be explained, which in some respects carried the investigation to still higher pressures and temperatures; these, however, lead to the same conclusion.

I propose this evening to deal chiefly with the practical or engineering side of the subject, and to review the limits of pressure and temperature which are artificially attainable, and to make some comparison between them and the pressures and temperatures occuring in Nature.

When the blade of a knife is pressed strongly against another blade so as to make a dent in each, the pressure on the boundary surface of the metal at the notch will have averaged from 300 to 350 tons per square inch according to the hardness of temper of the steel. The pressures of the knife-edges of a weighing machine when fully loaded are also of the same order.

When a needle is broken or a piece of piano-wire is strained to the point of breaking, the maximum tension on the metal will be at the rate of 150 tons per square inch. On the other hand, the pressures that occur in the chambers of large guns do not usually exceed 20 tons per square inch, and the tensile stress on the plates of a ship in heavy weather should not exceed 8 tons per square inch. From these simple instances some idea is gathered of the limitations imposed by materials and dimensions upon apparatus for experimenting at high pressures because of the practical difficulty of hardening and tempering steel in large masses.

When dealing with small amounts of material in each experiment the dimensions permit of making the container and the ram of tungsten steel, which can be hardened and tempered throughout, and not only superficially, as in the case of ordinary carbon steel. The material is hard and strong, but not brittle, and it retains these qualities up to moderate temperatures, such as 600° C., to a much greater extent than any other steel.

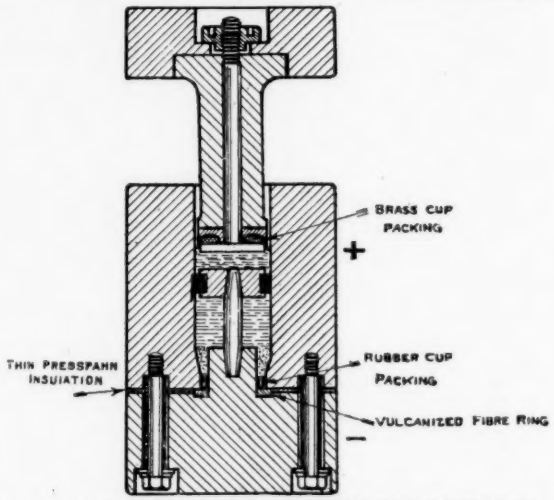


FIG. 1. CONTAINER ADAPTED CHIEFLY FOR COMPRESSING LIQUIDS

In one form of container or dies the bore is 1½ in. in diameter, and it may be used for a limited number of times for a pressure of 200 tons per square inch. It will, however, eventually crack if this pressure is many times repeated, the crecks usually beginning near the bottom of the die.

For still higher pressures it is better to use a double re-entrant container with two rams ½ in. in diameter. Both the container and the rams are made of hardened and tempered tungsten steel, and are rendered fluid and gastight by mild steel cups on the ends of the rams.

If the charge occupies only a short length of the bore, as shown, the barrel of the container where the charge lies is supported by the shear strength of the metal above and below the zone of pressure in addition to its own strength as a tube. Under these conditions it is as strong as or stronger than the crushing strength of the rams, and pressures of 300 tons per square inch may be repeated several times without cracking.

In a container of this form several grains of fulminate of

mercury have been placed, embedded in graphite, and the pressure increased very gradually until it reached 230 tons per square inch (under this treatment fulminate does not usually detonate). The die was then heated by gas to more than 180° C., the temperature of detonation. After two failures of the experiment, owing to the leakage of the steel cups, the third was successful, and no gas escaped and the container was uninjured. The graphite was somewhat caked, but otherwise unaltered. Graphite mixed with sodium nitrate and fulminate was also exploded under the same condition. Graphite with 15 per cent of potassium chlorate detonated when 200 tons per square inch had been reached.

Many other reactions were tested in a similar manner in larger dies under pressures of from 40 to 200 tons. The action of concentrated sulphuric acid on sugar was accelerated by a pressure of 50 tons, but, on the whole, these experiments in dies failed to produce any interesting results.

Unfortunately, the heating of the die with its charge cannot be carried much above 500°C. without serious weakening

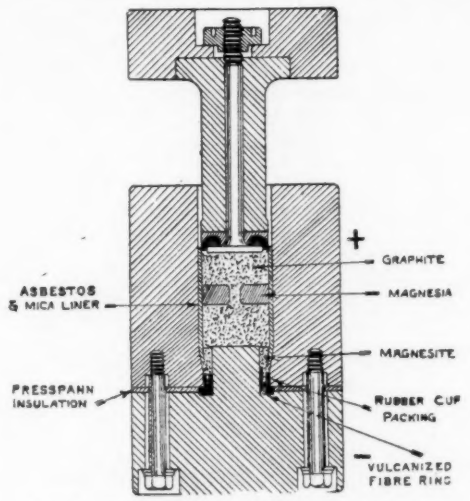


FIG. 2. CONTAINER FOR MELTING CARBON

of the steel and compelling a reduction of pressure. The electrical heating of the charge in such small dies, while keeping the die cool, presents great difficulties in electrical insulation on so small a scale to withstand intense pressure, but I think it might be accomplished in certain instances.

It has been suggested, with the object of reaching higher pressures, that a small die might be bodily immersed in a large container. Doubtless it could be arranged, but it would be very cumbersome to work with, and would only add about 100 tons per square inch to the maximum pressure.

A better plan would be to follow the principle of the usual capped armour-piercing projectile, and to reinforce the rams and ends of the container by tightly fitting copper or bronze rings around the necks of the rams, keeping the parallel part of the noses as short as possible.

When in operation the copper rings will be flattened and squeezed against the necks and shoulders of the rams, and also against the ends of the container, and by this means the parts that ordinarily would have to bear the maximum stress will have part of this stress transferred to other parts not so heavily stressed, and, consequently, the maximum pressure in the container can by this means be raised considerably, perhaps to 450 tons per square inch.

In carrying out experiments on larger samples of material and in applying electrical heating to the charge, the container becomes too large to permit of its being made of hardened steel; therefore, nickel-steel is used, as for the barrels of guns. It is heat-treated by quenching in oil from a high temperature after rough machining. Containers (Figs. 1 and 2) with the thickness of wall equal to the diameter of the bore will stand an internal pressure of 40 tons per square inch repeated almost indefinitely without serious enlargement of the bore, but 100 tons necessitates reboring and fitting of new packing to the ram after each experiment.

Fig. 1 shows the arrangement for electrically heating conductors immersed in fluids under high pressure. The packing of the ram is a cup leather-backed by a cup of brass; the leather first takes the pressure, and the lip of the brass cup is thereby expanded tightly against the bore of the container, and remains fluid-tight even though the leather should be carbonised by the heat. The bottom pole is electrically insulated from the container by vulcanized fiber washers and a rubber cup-ring, which is proteced from the heat by magnesite stemming.

The current is conveyed lrom the container to the top pole-piece of the conductor by pads of copper gauze, which can slide easily against the bore of the container and allow for the expansion of the conductor. Experiments on liquids with this container under 4400 atmospheres gave the same results as my former experiments under 2200 atmospheres.

Fig. 2 shows the container arranged to melt graphite under pressure by resistance heating. Here the charge is graphite, and is divided by the bridge or ring made of pressed calcined magnesia or titanium oxide. The bore of the container is electrically insulated from the graphite by layers of asbestos, millboard, and mica.

The calories evolved in the combination of graphite and oxygen are about 0.5 per cent. less than those evolved in the combination of diamond and oxygen, indicating that graphite at ordinary temperature is, to this extent, a stable state. The bulk-pressure which has operated in some of the experiments would, however, seem to have been amply sufficient to turn the balance in favor of diamond instead of graphite. The uncertainty, on the other hand, as to the compressibilities and specific heats of the allotropic forms of carbon under high pressures and at high temperatures renders speculation of little value as to what may occur at the melting point of carbon. All we know is that, up to the pressures and temperatures reached in our experiments, no indication of a change from graphite to diamond has been produced. In one experiment very intense heating was applied for five seconds, but sufficient in amount to melt the graphite core six times over, the only result being a slight alteration in the structure of the graphite. The barrier in this experiment was calcined magnesia, and the hole in it was superficially converted to magnesium carbide. It appeared, however, desirable further to investigate the possibility of carbon losing its electrical conductivity when approaching its melting point, as alleged by Ludwig and others, and of shunting the current from itself on to the contiguous molten layers of the insulating barrier surrounding it. There had been no indication of such a change having occurred even momentarily; it rather seemed that the graphite core had been partially vaporised and condensed in the cooler parts of the charge. The experiment was repeated with rods of iron and tungsten embedded in the core, so that should the temperature of volatilisation of the metals under a pressure of 15,000 atmospheres exceed that necessary to liquefy carbon under the same pressure, the presence of these metals, might produce a different result. No change, however, occurred.

Note.—The temperatures at which carbon, iron, and tungsten volatilise under a pressure of 15,000 atmospheres are unknown, but they are probably much higher than at atmospheric pressure.

This experiment also tested iron as a solvent of carbon and as a catalyst from diamond to graphite under a pressure of 100 tons, and showed that under this pressure that action was not reversed.

Fig. 3 shows the container arranged for treating powders by resistence heating with or without the addition of liquids or gases. The electric current is conveyed from the container

to the upper end of the conductor by a layer of graphite which rests on the charge under treatment. The bottom end of the conductor rests on or is spigoted into a cast-iron block which rests on the bottom pole; this block is sometimes partially melted, but can be easily renewed.

The container is charged by first stemming magnesite powder by hand around the bottom pole-piece and block; then the charge is placed on the top and pressed to 5 tons per square inch; the top ram is then removed, a hole drilled through the charge, and the conductor inserted. Liquids, if used, or carbon dioxide snow may then be introduced; lastly, a layer of graphite is placed on the top, and the whole pressed to the desired pressure for the experiment.

In one experiment several pounds of carbon dioxide snow were added to the charge, which consisted of magnesia, and was so arranged that evaporation of the heating carbon rod took place in an atmosphere of carbon dioxide and carbon monoxide under a gaseous pressure of 4400 atmospheres, the condensate resulting being soft graphite. Upwards of two

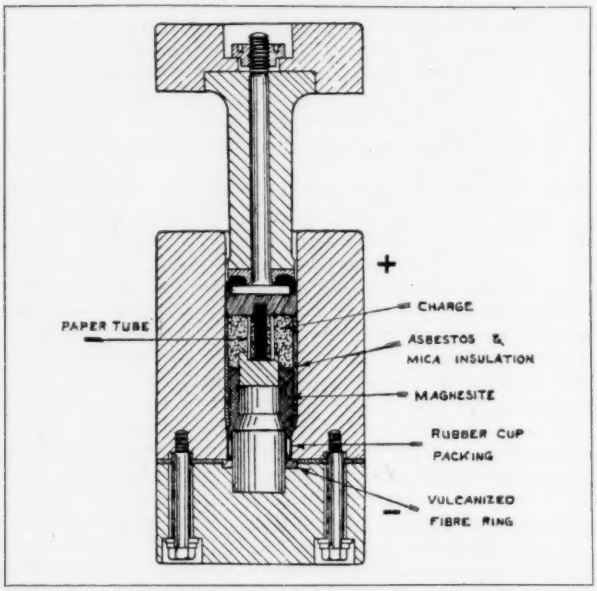


FIG. 3. CONTAINER FOR COMPRESSING POWDERS WITH OR WITHOUT LIQUIDS AND GASES

hundred chemical reactions arranged to deposit carbon were tested under high pressure and central heating. After each experiment samples were taken from various parts of the charge and carefully analysed for diamond, the methods of the analyses generally following those of Moissan and Crookes. On the whole, there was no evidence that diamond had been produced by any of the chemical reactions, some of which were endothermic, such as carborundum and sodium carbonate, which produced a grey solid which detonated when struck with a hammer, and nearly caused a serious accident. In one experiment the charge was olivine and water; when molten under 10 tons per square inch the pressure was suddenly removed, and artificial pumice was formed by the expansion of water-vapor absorbed by the olivine when molten.

Having nearly reached the limits of steady pressure obtainable in steel containers under a press, experiments with impact pressures produced by steel bullets were tried, which produced much higher instantaneous pressures than are obtainable in any die.

A rifle, 0.303-in. bore, was arranged for withstanding a charge of cordite 90 per cent. in excess of the Service charge. The gun (Fig. 4) was fixed with its muzzle 6 in. from a massive block of steel, in which a hole 0.303 in. in diameter had been drilled to a depth somewhat greater than the length of the bullet, and in alignment with the bore of the gun; cylindrical bullets of steel with a copper driving band were chiefly used, shorter than the Service bullet and about one-half the weight. The substance to be compressed was placed either at the bottom of the hole, when a conical-nosed bullet of mild steel was used, or over the mouth of the hole, when a cupped-nosed bullet of tool-steel was employed. About a hundred experiments were made.

The substances tested included graphite, sugar-carbon, bisulphide of carbon, oils, etc., graphite and sodium nitrate, graphite and fulminate of mercury, finely divided iron and fine carborundum, olivine and graphite, etc. After each shot the bullet and surrounding steel were drilled out, and the chips and entrained matter analyzed. Fig. 5 shows the bullet in the hole after firing.

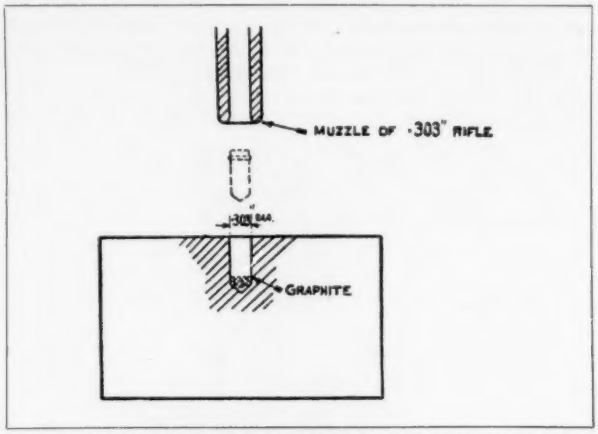


FIG. 4. PRODUCING HIGH PRESSURE BY FIRING A BULLET INTO A HOLE IN A STEEL BLOCK

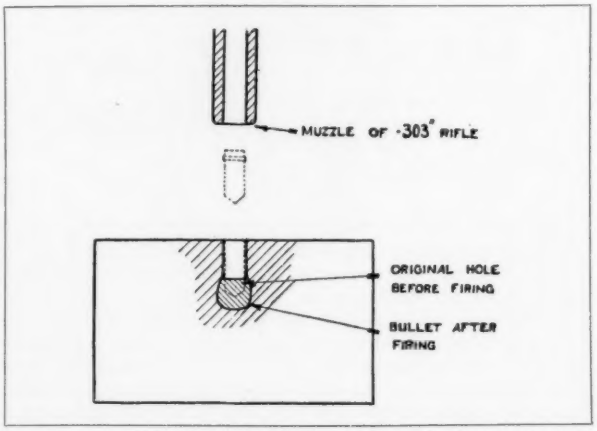


FIG. 5. EFFECT OF FIRING THE BULLET INTO THE HOLE IN THE STEEL BLOCK

Several experiments were also made with a bridge of arc-light carbon placed over the hole and raised to the limit of incandescence by an electric current, and the shot fired through it into the hole at the moment the carbon commenced to vaporise, as observed in a mirror from without. Also, an arc between two carbons was arranged to play just over the hole and the shot fired through it (Fig. 6). The residues were in all cases exceedingly small, and there was no evidence of any incipient transformation of carbon in bulk into diamond that could be detected by analysis.

The pressure on impact of a steel bullet fired into a hole in a steel block which it fits is limited by the coefficient of compressibility of steel; with a velocity of 5000 foot-seconds it is about 2000 tons per square inch. Measurements made from a section through the block and bullet (Fig. 5) showed that the mean retardation on the frontal face after the impact until it had come to rest was about 600 tons per square inch. Several experiments were made by substituting a tung-

sten steel block hardened and tempered, and a hole tapering gently from 0.303 in. at the mouth to 0.125 in. at the bottom. The mild steel bullet was deformed by the tapered hole, which greatly increased the velocity imparted to the nose. Progressively increased charges were used. With the 90 per cent. excess charge the block always split on the first shot, but this probably occurred after impact, and not until the full instantaneous pressure had been exerted, which was probably about 5000 tons per square inch, or about equal to that at the centre of the earth.

It would be interesting to repeat some of these experiments on a larger scale. With a projectile 6 in. or 9 in. in diameter and a velocity of 5000 foot-seconds, the instantaneous pressure would be the same, but its duration (which is proportional to the linear dimensions) would be increased from twenty- to thirty-fold. It has been estimated that the rise in temperature due to adiabatic compression of incandescent carbon when subjected to 2000 tons per square inch is of the the order of about 1000°C., so that actual melting of the carbon would probably have occurred when the shot was fired through the incandescent carbon bridge.

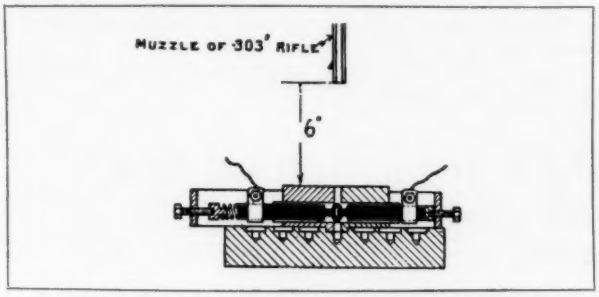


FIG. 6. FIRING INTO THE HOLE THROUGH AN ELECTRIC ARC

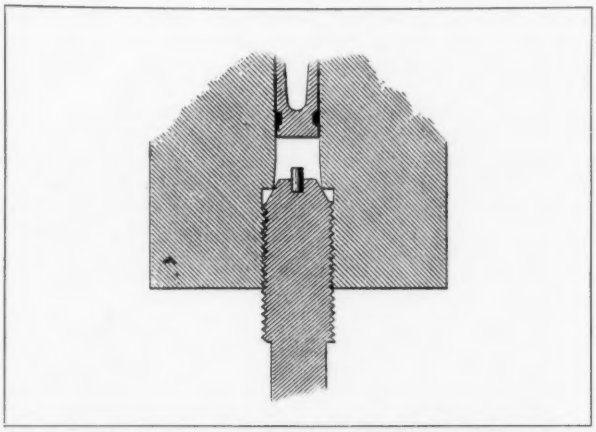


FIG. 7. THE STEEL BLOCK AND PISTON WHICH WAS FITTED TO THE RIFLE BARREL

Another experiment was arranged which would ensure that carbon should be subjected to an extremely high temperature concurrently with a high pressure obtained by the rapid compression of the hottest possible flame, that of acetylene and oxygen, with a slight excess of the former to provide the carbon. The arrangement was as follows (Figs. 7 and 8):—A very light piston made of tool-steel was carefully fitted to the barrel of a gun of 0.9 in. bore; the piston was flat in front, lightened out behind, and fitted with a cupped copper gas-check ring, the cup facing forward; the total travel of the piston was 36 in. To the muzzle of the gun was fitted a prolongation of the barrel formed out of a massive steel block, the joint being gastight; the end of the bore in the block was closed by a screwed-in plug made of tempered tool-steel, also with a gastight collar. A small copper pin projected from the center of the plug to give a record of the limit of travel of the piston. The gun was loaded with 2 drams of black sporting powder, which amount had been calculated from preliminary trials. The barrel in front of the piston was filled with a mixture of acetylene and oxygen. It was estimated that this mixture would explode when the piston had travelled about half-way along the bore. When fired, the piston travelled to within 1/8 in. of the end, as had been estimated, giving a total compression ratio of 288 to 1. As a result, it was found that the surfaces of the end plug, the fore end of the piston, and the circumference of the bore up to ⅜ in. from the end of the plug had been fused to a depth of about 0.01 in., and were glass-hard; the surface of the copper pin had been vaporised, and the copper sprayed over the face of the end plug and piston. The end plug, which had been hardened and tempered to a straw colour, showed signs of compression, and the bore of the block for ⅜ in. from the plug was enlarged by 0.023 in. in diameter, both indicating that a pressure above 100 tons per square inch had been reached. A little brown amorphous carbon was found in the chamber, which was easily destroyed by boiling sulphuric acid and niter. There was no diamond residue from this. Considering the light weight of the piston and the very short duration of the exposure to heat, the effects would indicate that a very abnormal temperature had been reached, many times greater than exists in the chambers of large guns. A calculation made by Mr. Stanley Cook, based upon the ratio of compression and a final pressure of 15,000 atmospheres, indicates that a temperature of between 15,250° and 17,700° C. was reached, the exact temperature depending upon the amount of dissociation or combination existing between the elements at the time.

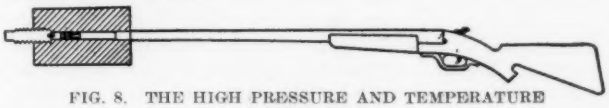


FIG. 8. THE HIGH PRESSURE AND TEMPERATURE EXPERIMENT

Calculation by Stanley S. Cook of the Temperature Reached in the Experiment of Compressing a Flame of Acetylene and Oxygen.

The temperature reached may be estimated from the final pressure, which the observed deformation of the block and plug indicates to have been in the neighborhood of 100 tons per square inch. But it must be remembered that there is a change of molecular volume as a result of combustion. Thus the mixture, which as C_2H_2 and $5(O)$ has $3\frac{1}{2}$ molecular volumes, would on combustion to $2CO_2$ and H_2O have only 3 molecular volumes. The final temperature deduced from the pressure will therefore depend upon the extent to which chemical combination has taken place.

The original mixture being at atmospheric pressure and at a temperature of 290°C. absolute, a pressure of 100 tons per square inch, after compression to 1/288th of its original volume, would indicate a temperature of 15,250° C. If, however, complete combustion has taken place, this pressure would correspond to a temperature greater in ratio of $3\frac{1}{2}$ to 3, viz., to 17,700°C. The actual temperature must therefore have been something between these two values.

Let us for a moment consider the pressures and temperatures possible in Nature (in this I am indebted to kind assistance from Prof. Jeans). The pressure at the centre of the earth is between 4,000 and 10,000 tons per square inch, according to the variation in density of the concentric layers.

Emden has estimated the probable pressure at the center of the more massive component of the binary star S Hercules to be 360,000,000 tons per square inch.

Again, the densities of the brighter components of certain binary stars are estimated by Opik to be about that of iron, and if we assume that their diameter is the same as that of the sun, that each has an initial velocity in space not greater than 30 miles per second, and that they directly collide, then, owing to their mutual attraction, Jeans calculates that

their velocity will have increased to 450 miles per second, and that the pressures in the center as they strike and flatten would be of the order of 1,000,000,000 tons per square inch. He also estimates that the heat equivalent of the energy would be sufficient to vaporise the whole mass 100,000 times over. This immense pressure would be maintained for many minutes, perhaps for half an hour.

Let us consider what is the greatest pressure that can be produced artificially. If the German gun which bombarded Paris were loaded with a solid steel projectile somewhat shorter and lighter than the one actually used, a muzzle velocity of about 6000 foot-seconds might be reached (many years ago Sir Andrew Noble had reached 5000 foot-seconds); and if it was fired into a tapered hole, as I have described, in a large block of steel, this would give the greatest instantaneous pressure that can be produced artificially so far as we at present know, viz. about 7000 tons per square inch; it is only about 1/150,000th part of that possible by the collision of the largest stars.

As to the temperature and conditions of matter under these intense pressures, extrapolation from known data is valueless. We have no knowledge of the coefficients of compressibility of matter under these conditions or of its specific heat. What may be the effect on the atom? And will elements under such conditions be transformed into others of higher atomic weight?

Some of us may recall that in 1888 a lecturer, after describing in this room the experiment in which oxygen at atmospheric pressure was passed in close contact with a platinum surface heated by the oxyhydrogen burner to nearly its melting point, and then immediately cooled by contact in water, said:

"In this experiment ozone is formed by the action of a high temperature, owing to the dissociation of the oxygen molecules and their partial recombination into the more complex molecules of ozone. We may conceive it not improbable that some of the elementary bodies might be formed somewhat like the ozone in the above experiment, but at very high temperatures, by the collocation of certain dissociated constituents and with the simultaneous absorption of heat."

It seems indeed probable that the centers of the great stars and stars in collision may be the laboratories where the elements as they gradually degenerate are being continually regenerated into others of higher intrinsic energy, and where endothermic processes, such as the recombination of lead and helium into radium, may be taking place, absorbing in this process an energy 2,500,000 times that developed by the explosion of an equal weight of T.N.T.

The transformation of only a minute fraction of the mass of two colliding stars would therefore be amply sufficient to absorb the whole energy of their collision.

Emerson said many years ago, "None but the elements can themselves destroy."

Manufacture of Carbon Black from Natural Gas*

Utilization of Low Pressure Gas in Fields Abandoned by Gas Companies

By Roy O. Neal

THERE seems to be some confusion between the terms carbon black and lamp black, although in American trade lampblack is generally understood to be a soot formed by the smudge process. In this process oil, coal tar, resin or some solid, or liquid carbonaceous substance is burned in an insufficient quantity of air, while on the other hand carbon black is a product resulting from the incomplete combustion of gas and is deposited by actual contact of flame upon a metallic surface.

The various carbons, such as gas retort coke, oil retort coke, graphite, carbon black, lampblack, vine black, wood pulp black, willow charcoal, and blacks made from refuse material such as leather have different characteristics as to flocculence, strength of color, and physical structure. These blacks are made by one of the following methods:

(1) Formation by direct contact of a flame upon a depositing surface.

(2) Production by combustion of an oil, tar, etc., in an inadequate supply of air; the soot is allowed to slowly settle out on the floors and the walls of the collecting chambers.

(3) Carbonization of solids and subsequent reduction to a state of small subdivision.

(4) Production by heating carbonaceous vapors or gases to a decomposition temperature by external heating, with or without air in the forming chamber.

Each black has its specific use that in most cases cannot be met by another black. It is often difficult to apply the usual tests to determine which to use on account of the modification in properties upon combination with other substances. In what follows the black resulting from the incomplete combustion of natural gas is taken up and is designated as carbon black although often in the trade it is referred to as gas black, natural gas black, ebony black, jet black, hydrocarbon black, satin gloss black, and silicate of carbon.

The estimated production of carbon black for the year 1918 was 43,500,000 pounds, of which 30,000,000 pounds was manufactured in West Virginia, and only 1,500,000 pounds was manufactured in Oklahoma. This year will probably show a decrease in production of West Virginia and a material increase for Louisiana, where a large number of plants have recently been built. In the Monroe, Louisiana, gas field, which is probably the largest in the world today, the gas can be obtained for two cents per thousand cubic feet, whereas in West Virginia the carbon-black operators are paying about three cents. The industry is necessarily a migratory one and usually finds its home in an isolated district where there is an abundant supply of gas with insufficient marketing facilities. Judging from plant production, the average yield of carbon black in pounds per thousand cubic feet is probably 0.85 for Louisiana, 1.10 for West Virginia, 1.1 for Oklahoma and 1.4 for Wyoming.

The estimated distribution of carbon black per annum is:

	Lbs.
Rubber industry	20,000,000
Printers' ink	10,000,000
Export	8,000,000
Stove polish	4,000,000
Phonograph records	500,000
Other uses	1,000,000

Under other uses are paint, carbon paper, type ribbon, tarpaulins, carriage cloth, black leather, paper, bookbinders' board, shoe polish, electric composition insulators, celluloid, buttons, etc. At present the export trade is small, pending the establishment of a stable basis of credit with Germany and Austria, but considerable quantities are shipped to England, France, Japan and China. During pre-war times one-third of the annual production was exported.

The first carbon black made in 1872 sold for $2.50 per pound; this price rapidly decreased until it reached the low mark of five cents per pound in 1912. In 1915 support was given the carbon black market when the beneficial results of the use of carbon black in rubber tire-making was discovered. The market price of carbon black has increased and has not since fallen below eight cents, during the past two years it has sold for as much as sixteen cents. The grade

*From Monthly Reports of Investigations of the U. S. Bureau of Mines.

of black above mentioned is that used by the rubber and newspaper ink trade, and constitutes the bulk of the production, although there are some grades, such as the Peerless black that bring as much as thirty-five cents at the present time. The latter is used in limited quantities in making embossing and high grade lithographic ink.

When planning the construction of a carbon-black plant, information on the following points should be obtained: distance from railroad or navigable stream, depth of wells, thickness of gas-bearing strata, gas pressure, gasoline content and knowledge as to whether gas is casing-head or dry, amount of proven territory, history of field, drilling practice, location of field in regard to large centers for domestic and industrial distribution of gas, distance from large trunk pipelines for transportation of gas, open flow capacity of gas wells on prospective leases, and a test on the richness of gas for the approximate quantity of carbon black that one expects to procure per thousand cubic feet.

The carbon black value is determined either by chemical analysis of the gas or by a test apparatus in which a known quantity of gas is burned and the carbon black that is deposited upon a plate is collected and weighed. By chemical analysis the yield of carbon black is computed from the percentage of ethane, heating value, and the carbon content. Louisiana gas contains 3.44 per cent ethane, has a heating value of 962, a carbon content of 33.8 lb. per thousand and only 0.8 of a pound is obtained per thousand cubic feet; whereas Wyoming gas which contains 43.1 per cent ethane, has a heating value of 1176, and a carbon content of 44.3 lb. per thousand, the yield is 1.4 pounds. There are four commercial processes of making carbon black classified according to the quantity of carbon black produced. The order is as follows: channel, small disk, large plate and roller processes.

CHANNEL PROCESS.

Briefly the channel process is as follows: The gas from the wells is reduced in pressure by suitable regulators, and then goes through gasometers that regulate the flow by a butterfly valve. The gas then passes to the burners in the condensing buildings, special precautions being taken in the pipe-line design to obtain equal distribution of gas in all the buildings. The condensing buildings are sheet-iron buildings about 100 feet long and from 10 to 8 feet in width, arranged in rows along both sides of an alley. Through the center of the alley, and at right angles to the condenser units, is the main driving shaft, which operates the machinery within the units.

On the interior of the buildings are tables of channels, beams having eight 8-inch channels that travel on trucks supported by a trestle 6 feet high and 66 inches wide. The channels have a reciprocating motion of about 55 inches. The gas is burned through ordinary lava tips with an even, luminous, and smoky flame, the draft being regulated by a slide door or slits at the base of the buildings or by the chimneys. There are about 1600 tips per building. The carbon black is deposited upon the underside of the channels. Underneath the channels and spaced every four feet are sheet-iron hoppers to catch the carbon removed by scrapers set in the hoppers. Connected to the hoppers is a spiral conveyor that carries the black to the bolting room. The bolters are galvanized sheet-iron drums having a layer of 45 to 60-mesh iron screen held by heavy wire as reinforcement over which fiber brushes rotate; the purpose of the device is to remove grit, scale and like material. From the bolters, the product is elevated by an endless chain to a storage bin, whence it is packed in 12½-pound sacks.

The plants are usually built in 60-barrel units (50 pounds per barrel) and have 18 buildings. The channels and other moving mechanism weigh about 200 tons. This is actuated by a 20 to 25-h.p. internal combustion gas or expansion engine. The operating cost is about 2 cents per pound (exclusive of cost of gas) and the construction cost at present is about $2,500 per barrel per day.

ROTATING DISK.

The disks are made of cast iron, 36 to 40 in. diameter, having a 6-in. face and, together with the gear and pinion, resemble flat umbrellas. The hopper and scraper radiate from the shaft and, like the burners, are stationary. The burners are in the form of rings with lava tips inserted about the upper part of the ring. The disks are set in rows of 21 each, with four rows to the condensing building, and a separate driving shaft for each row of disks. The pinions are of special design having teeth about 4 inches wide that mesh with 2-inch teeth on the gear. This arrangement is to take care of expansion and contraction. Other details of the plant are the same as in the channel system.

PLATE PROCESS.

The plates upon which the carbon black is deposited are 24 feet in diameter, and made up of 48 segments, which are supported by a central mast and cables. The plates are stationary while the burners and scraper rotate, making one revolution every eight minutes. There are 1265 tips to each plate. The plates are surrounded by a circular building 26 feet in diameter, made of corrugated sheet iron. The conveyor system, bolting, and packing process are the same as in the preceding systems. One company has as many as 113 rings and a daily production of 10,000 pounds.

ROLLER METHOD.

In the roller process the gas is burned through lava tips, having a round perforation instead of fish tail. The rollers are 8 inches in diameter and three feet in length, making one revolution in thirty minutes. The scrapers are set on top of rollers and scrape continuously. From 6 to 9 rollers are inclosed in one hood. In one plant visited there were 1150 rollers and 40,000 tips, with a production of only 300 pounds per day. The yield per thousand cubic feet is very small but the product commands a high price, about 35 cents at present. It is used in making embossing and high grade lithographic inks.

THERMAL DECOMPOSITION.

Thermal decomposition, or the subjection of oil vapors or gas to cracking temperatures with or without the presence of air, is not a commercial success at present inasmuch as the resulting carbon is heavy, contains tarry matter and is off color. A company in western Oklahoma erected a cracking chamber for making black from natural gas and found that the product was salable. A jobber said that it was not good for any purpose except perhaps to blacken the face of a minstrel. The process, however, furnishes a promising field for future research. Possibly by using a properly designed cracking chamber, sudden cooling, using some catalyser, employing pressure or the admission of a suitable quantity of air, the process will become a commercial success and capable of producing a black having the same properties possessed by the ordinary carbon black on the market today.

ECONOMICS OF CARBON BLACK INDUSTRY.

It is generally conceded that the most useful purpose that natural gas can be applied to is for domestic consumption, but whether gas is of greater economic value for the manufacture of carbon black than for other industrial uses is a question that must be decided on the basis of conditions existing in each locality in which a large supply of natural gas is available.

The utilization of low-pressure gas, discharge gas from natural gas gasoline plants, gas in isolated districts, and fields which have been abandoned by other gas companies on account of low pressure, for the manufacture of carbon black, is in reality often a conservation measure and is preferable to the common practice of letting the gas go to waste.

The utilization of natural gas for domestic consumption is possibly the most beneficial use that can be made of gas, and it is not recommended that gas be used for the manufacture of carbon black where there is an available market for the gas for domestic purposes.

High Temperature Electric Heat-Treating Furnace

Development Due to the Emergency of the War

By Geo. H. Holden, Assist. Inspector of Ordnance, U. S. N.

BEFORE the declaration of war against Germany, the naval arm of America's military establishment had made an intensive survey of the varied industrial facilities. This, to a large extent, had been prepared through the assistance rendered by combined engineering societies to effect a complete industrial inventory, which, at the outbreak of the war, was practically compiled, so that sources of all material were available. Thus the naval program of expansion—preparation—perfection—permitted the Navy Department to place large contracts with America's chosen industries, whose later accomplishments, excessive production and excellence of quality would be recorded of the stimulus and foresight of the preparation already outlined.

To produce guns to fit out this large naval expansion was of such magnitude that it would confound any citizen not familiar with the activities incident thereto. The arming of all transports, supply boat, sub-chasers and tugs was imminent.

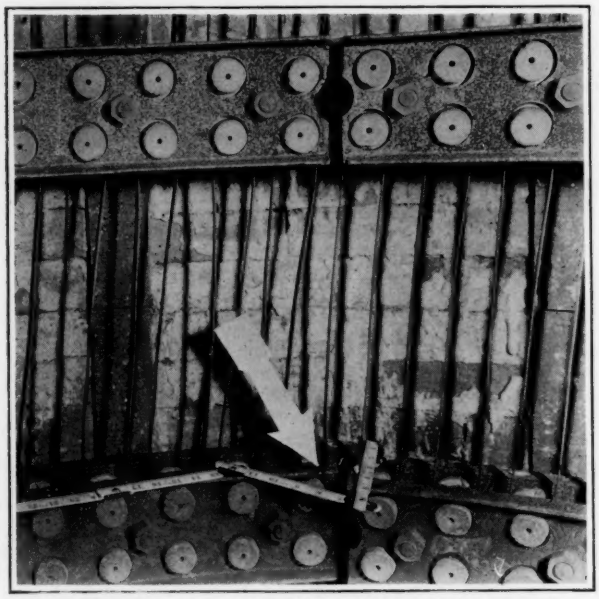


FIG. 1. EFFECT OF VARIATIONS IN EXPANSION OF THE PORCELAIN REFRACTORY INSULATORS

Also to insure that sea food would be available for our large growing population it was even necessary to arm the offshore fishing boats. As the reader will recall a number of atrocities were committed within the three-mile limit of our eastern shores by German marauders.

The supply of gun forgings was confined to a half dozen manufacturers throughout the United States. The tonnage which the Navy demanded was only obtainable through immediate expansion and even though this expansion could not be readily accomplished, because the foregoing companies were worked to capacity, they did not have the capital sufficient to expand to meet the emergency demands of the Navy and further did not care to assume the risk of the war's terminating, possibly, before emergency extensions were accomplished. The War Industries Board, which had cognizance of the manufacturing facilities, directed, therefore, that expansions be made and subsequently cost-plus contracts were entered into whereby the cost of expansion of various plants was paid for by the Government, the manufacturer assuming the responsibility of operating and producing material required.

The writer will endeavor to present the actual production, on a major basis, in connection with the heat treatment by high temperature electric furnaces, on one of the large contracts.

Prior to the actual construction of these furnaces considerable discussion was entered into as to the practicability of installing this type of furnace, owing to the fact that such data available was anything but encouraging and generally considered still in the experimental stage, as during 1915 and 1916 one of the large steel companies had conducted extensive experiments with several high temperature furnaces both of the experimental type and the commercial, and had collaborated with prominent electrical authorities to the end that considerable success and information was obtained.

The following points are briefly presented for analysis, which will express characteristics both favorable and unfavorable, based largely on the fact that maximum temperatures

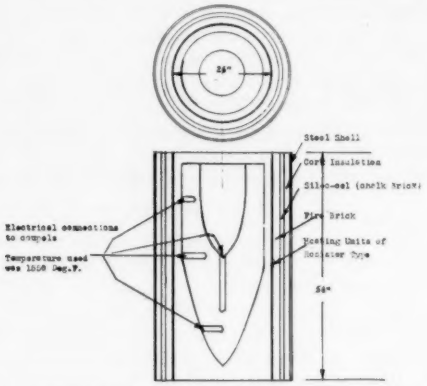


FIG. 2. EXPERIMENTAL FURNACE OF RESISTOR TYPE

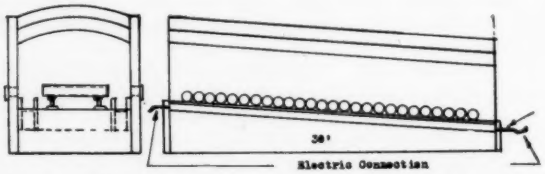


FIG. 3. LATER TYPE OF FURNACE EMPLOYING A BED OF GRAPHITE FOR THE HEATING ELEMENT

of at least 1,600 degrees are necessary in treatment of steel forgings. This particularly in such cases as do not respond to the required static covered in the specifications.

In connection with a few electric resistor type furnaces, the low temperature type has proven a success and it can be said that the experimental stage is over and was used extensively during the war for shrinkage and general manufacturing purposes where temperatures ranged 1,000 degrees F. or less.

Where maximum temperatures exceed 1,000 degrees F. the electric furnaces have the following invaluable characteristics.

The insulation, which to date 1917 has been adapted, has been absolutely erroneous and to some extent has been partially overcome, therefore, this type of furnace is still in the experimental stage and certain phases of the same when overcome will prove that the prospects are very hopeful.

It is most important that construction of furnaces be such that no metallic members be directly exposed to the high tem-

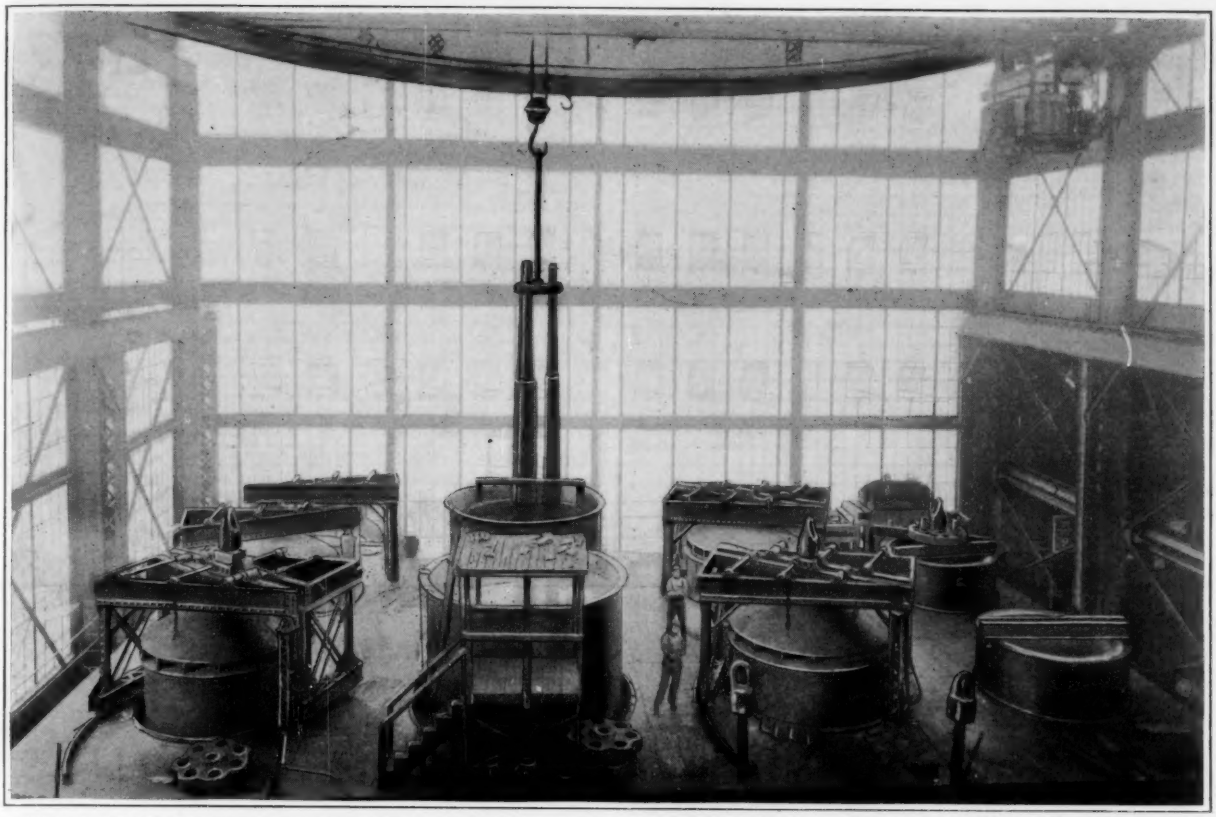


FIG. 4. ELECTRIC FURNACE EQUIPMENT APPROVED BY THE NAVY DEPARTMENT. FOUR HIGH TEMPERATURE RESISTOR TYPE FURNACES, TWO QUENCHING TANKS WITH CAPACITY OF 11,800 CUBIC FEET OF WATER AND TWO COOLING STACKS

peratures due to coefficient of extension or expansion and contraction of same, except when adaptability will prove practicable and where furnace design will compensate for same, as past experience has taught and demonstrated that simplicity and extreme strength are most essential when dealing with high temperatures.

As an illustration of this fact the Bureau of Standards in Bulletin No. 352 entitled Thermal Expansion of Insulating Materials, and No. 357, Coefficient Radiation, presents excellent data. In most cases the expansions are too irregular to justify the use of the general quadratic equations, but a thorough knowledge of the thermal behavior of the various materials which enter into the construction of this type of commercial furnace, will assure considerable success to the practical application of this theory, and the initial cost of installation.

The procelain refractory insulators used for suspending ribbons have a wide range of the coefficients, namely, from 1.6 to 19.6 millionths per unit length per degree centigrade. While this is considered insignificant from a practical point of view, its relation is obvious, however, when used in connection with the columns and channels of a metallic composition having a coefficient of extension expressed in inches, as will be noted in Fig. 1.

The point-contact couplings at best are unsatisfactory as the pressure to be applied is uncertain and so important. At best the utmost skill and patience is required to obtain temperatures and results are unreliable, as check temperatures are desirous at times in order that forgings may be successfully treated.

It is most indispensable that a coupling contact be made at point of diffusion in order that temperature of furnace may be controlled, as in treatment of forgings in multiples or hollow bored forgings. The furnace temperature proceeds at a more rapid rate in rising than the forging and to obtain uniformly heated forgings they must be allowed to saturate to the furnace temperature.

The various steel companies manufacturing gun forgings have attained a point of highest efficiency in the production of the same with the vertical oil-fired furnaces in which the human element is a large factor or characteristic concerned, particularly in keeping the temperatures throughout the length of forgings at a uniform temperature, or where a tapered temperature is desired, owing to the varying cross-sections of forgings.

If this uniform temperature is not maintained when forgings are quenched and subsequently drawn and tested non-uniform results in physical tests will be obtained.

One of the early experimental types of this resistor type of electric furnaces was successfully used in the heat treatment of 14-in. A. P. shells, but not until after the foregoing invaluable characteristics had been overcome, and it is not surprising that the experiments having this success had run over a period of one year, conducted by two leading electrical engineers.

This furnace, as shown in Fig. 2, was 26 in. inside diameter and 60 in. high. It was circular and a resistor type unit from which the treating plan under discussion was developed. At first, no control at point of diffusion was made and when the furnaces had attained the desired temperature current was cut out and before shell forgings was allowed to saturate uniformly throughout, the temperature at points where couplings had been inserted (in drilled holes) showed excessive variation, which should not vary more than five degrees to insure proper treatment. Subsequently couplings at point of diffusion were attached.

Another high temperature furnace was developed and after nine months of constant experimenting some success was at-

tained in the treating of 11½ in. French shells on a commercial basis. As may be seen in Fig. 3, this furnace had a refractory lined conduit on each side and the furnace was of the arch type gravity feed. About two bushels of graphite was consumed in 24 hours as the heating element. The graphite was laid uniformly along these conduits or troughs through openings at the ends and sides of furnace, thereby completing the electric circuit. The graphite was renewed constantly by laying same with a long handled shovel at points where graphite was about burned out. The uniformity of heat diffusion was controlled by this unique method of keeping the graphite at a uniform depth. This type of furnace gave constant trouble and was subsequently refitted with oil.

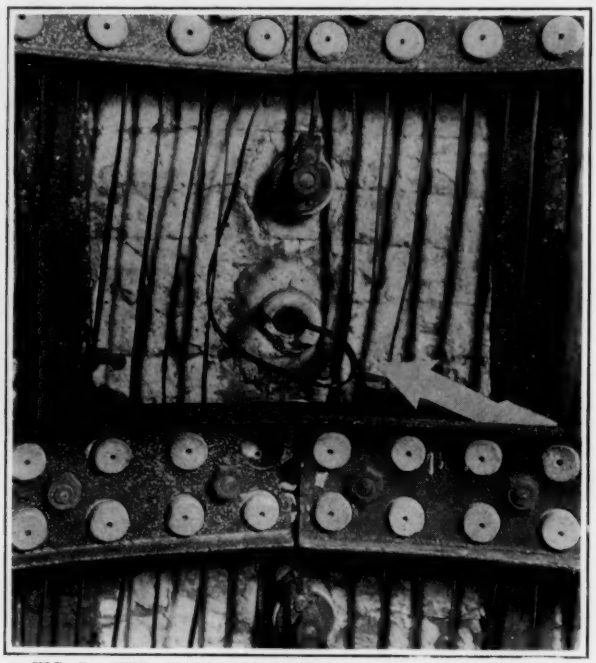


FIG. 5. THE NICHROME RIBBONS CONNECTED TO THE TERMINAL RODS

It was, therefore, recommended by officials familiar with the foregoing difficulties that two of the battery of electric furnaces be fitted with oil type connections to insure against delay in case any unforeseen difficulties should arise in the successful operation of these furnaces.

The contract required the total delivery of 5,000,000 of 3 in. and 4 in. gun forgings, delivery to begin six months after date of contract, to wit: 90 sets of 4 in. and 50 sets of 3 in. guns, per calendar month—or approximately 600,000.

To accomplish the heat treating of this large volume of material the company that received the contract were desirous of treating same by the electric process, which was a new departure unheard of on a commercial basis. However, with the Navy Department's approval, a proposition was received from one of America's leading electrical manufacturers, which submitted a proposal to install four high temperature heat treating furnaces and received a tentative contract during July, 1917, to proceed with the construction of the same.

Specifications

Furnaces—27½ ft. high, 6 ft. inside diameter.
High Temperature Hardening Furnace, 400 Kw. 440 volts.
Operating temperature 1,500 degrees F. Max.
Charge—16,000 pounds steel.
Thermal capacity, 1,500 degrees F. (2,000 Kw. H. Approx.)
Radiation—50 Kw. H. (Approx.)
Furnace constructed per G. E. design, 9 in. heat lagging.

Guarantees.

Operating at 440 volts, (A) Furnace at 600 degrees F., charged with 16,000 pounds steel at 60 degrees F., economy will be not less than 6 pounds per Kw. H.; Cycle of heating—6 hours. (B) Furnace at 1,500 degrees F., charged with 16,000 pounds steel at 60 degrees F., economy will not be less than 8 pounds per Kw. H. Cycle of heating—3½ hours. Allowing 1 hour for forging to soak at 1,500 degrees F.

The electric furnace, as approved by the Department, Fig. 4, was to consist of four high temperature resistor type furnaces, two quenching tanks of 11,800 cubic feet of water capacity and two cooling stacks. Furnaces were made up of a steel shell 10 feet in diameter in which a 12 in. floor of fire brick, asbestos cushioned was laid. In a vertical position a metal column frame of calorite metal was erected. After the calorite frame was set, centered and shored, a refractory lining was inserted between it and the steel shell, and starting from the frame studs, consisted of one row of high grade silica brick backed by two rows of "Silocel" and a packing of about two inches of wool asbestos. The furnace face of this lining was then grouted and made air-tight at all joints. Special refractory tube insulators afforded entry for terminal rods. between channels, spools of highly refractory (silica) material was inserted and on these a nichrome ribbon was wound.

This winding is well illustrated in Fig. 5. Resistors or terminal couples are attached and after inspection of ribbons for contacts, the covers of the furnaces are hung. Flanges on the bottom of the cover castings sink into a sand layer on the top of the furnace lining and serve as an air seal. The covers are built up of two sections—half domes—lifted by air valves and supported by a frame superstructure which rolls out from furnace on standard rails and thus give clearance of the full diameter of the shell for the charging and withdrawing of pieces treated. The design and operation of these covers are illustrated in Fig. 4.

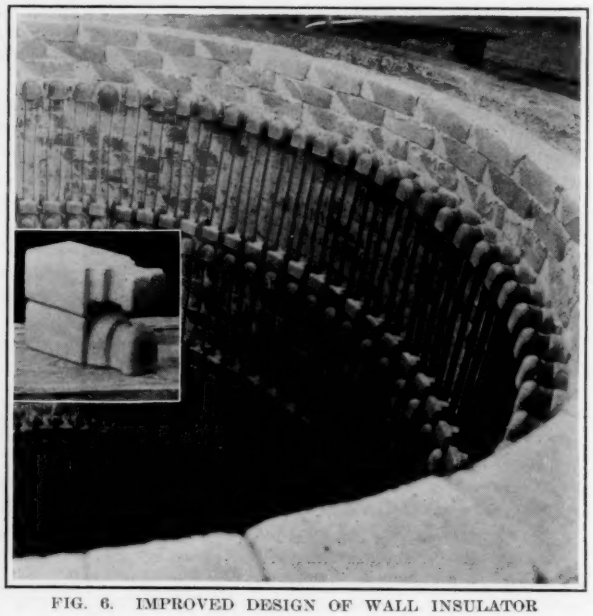


FIG. 6. IMPROVED DESIGN OF WALL INSULATOR

The temperature range is effective from 800 degrees F. to about 1,800 degrees F. and while a maximum high range of 1,500 degrees F. is used, 300 degrees higher has been attained without inconvenience or danger to insulators or ribbons. The only visible effect was the distortion of the metal frame-work of calorites or aluminum steel. On the experimental bench, ribbons have stood up to 2,500 degrees F. without bad results.

The furnace is divided into four zones each under separate

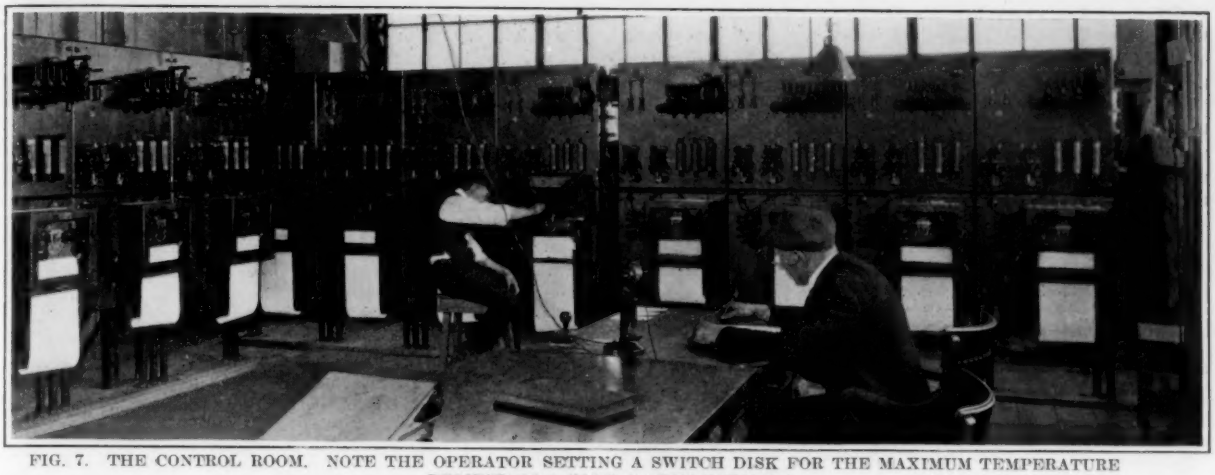


FIG. 7. THE CONTROL ROOM. NOTE THE OPERATOR SETTING A SWITCH DISK FOR THE MAXIMUM TEMPERATURE DESIRED IN A ZONE OF THE FURNACE

and independent thermal control, which gives greater elasticity of temperature range and enables the metallurgist to compensate by graduated resistance for the idiosyncrasies of transformation in the quench, which affects different sections of metal with greater or less degree of hardness or high static values. Each zone has an independent Leeds-Northrup self-recording pyrometer. The pyrometer is equipped with a three wire motor driven commutator controlling a galvanometer which acts directly upon a switch disc. The setting of this disc governs the maximum temperature desired and the maintenance of that temperature when it is reached. Fig. 7 shows an operator in the act of setting a disc. Hardening and drawing furnaces are operated alike with the exception that while a uniform temperature is maintained on hardening, the graduated or step temperature is applied on draw heats with excellent results in the uniformity of physical characteristics obtained in breech and muzzle ends of parts treated.

The writer will endeavor now to present the actual troubles, developments and rectifications which were necessary to place the foregoing high temperature furnaces on an efficient working basis.

Shortly after assumption of work on these furnaces, it was found that resistor couples, which were of mechanical design, were deteriorating very rapidly and in some cases caused ribbons to become loose, and resulted in arcs which burnt off the ribbons. This caused loss of the zone and necessitated cooling down of the whole furnace to effect repairs—the time loss and overhead costs accumulating through these repairs made the condition serious.

It was found that certain segments and columns were scaling so heavily that large pieces falling on channels between resistance series caused numerous arcs which would also burn nichrome ribbons in two, causing great time losses in operation on account of repairs and replacements of ribbons. At this time unsuccessful attempts had been made to weld burnt ribbons.

The necessity of reducing this time loss resulted in experiments on the welding of nichrome ribbons carried on by manufacturers of these furnaces. Success attended the experiments and a modification was made in the elimination of the mechanical couple, by welding the ribbon directly on the terminal rod. Likewise this welding of nichrome eliminated the mechanical ribbon splice (see Fig. 5). Discovery of air inlets at terminal entrances brought about a correction of heavy scaling problem. A careful seal of all openings, electrical and optical, proved a remedy.

A new trouble developed about 30 days after starting of furnaces, namely the distortion and deterioration of the metallic frames. This had been anticipated and the subsequent elimination of the metallic frame and substitution of refractory insulators, directly into wall, as early as October, 1917, resulted. Owing to the novelty of furnace design and inex-

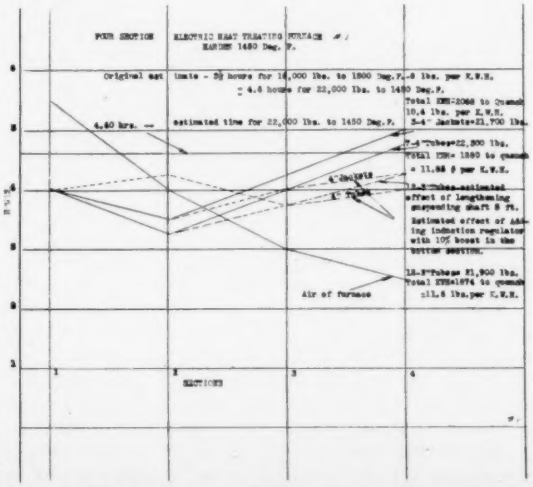


FIG. 8. TIME REQUIRED TO REACH TEMPERATURE FOR 3-IN. TUBES, 4-IN. JACKETS AND 4-IN. TUBES

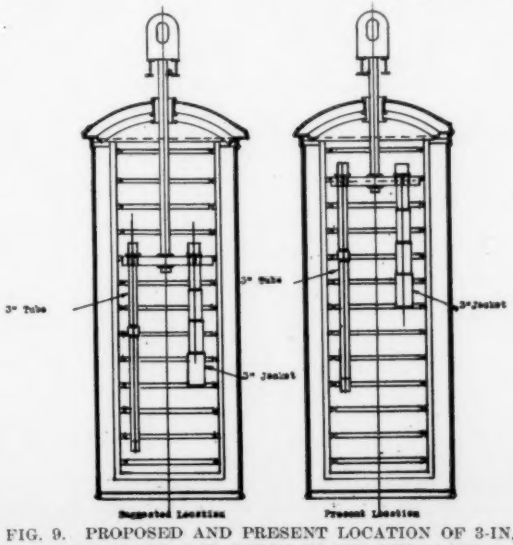


FIG. 9. PROPOSED AND PRESENT LOCATION OF 3-IN. JACKETS AND 3-IN. TUBES IN THE FURNACES

perience of the general heat treating personnel on electric furnace resistance on so large a scale, practical application of this suggestion did not develop at this time. However, distortion developed into such serious proportions that the plug or wall insulator was again given attention and submitted to the Bureau of Ordnance which directed that the furnace be immediately equipped with this insulator, and now it is possible to reduce the initial construction costs of electric furnaces for treating forgings 60 to 70 per cent (see Fig. 6).

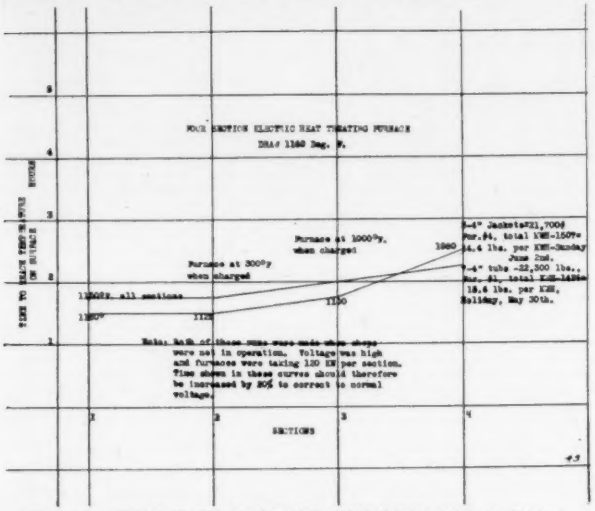


FIG. 10. CURVES OF DRAW IN FURNACES NOS. 1 AND 4. NOTE THAT CURVES CROSS DENOTING DEFECT IN HEAT INSULATION OF FURNACE NO. 1

The innovation of electric furnace heat treating has proved, beyond contention that this method has done more than to compare favorably with the older oil and gas fuel methods. The cost of power consumption as compared with that of fuel oil used in this plant for the heating medium—due to time factors and control of results possible with the electric furnace, and figured pound for pound raised to same temperature and held there—has been approximately 20 per cent lower.

The series of tests referred to in the following remarks were conducted on the furnaces and were made to investigate and check the furnaces while in actual full load operations, one against the other, to check efficiency of same and to see that specifications and guarantee of manufacturer had been met and further to effect proper certification of invoices covering final payment of same.

Fig. 8 shows the time required to reach temperature for 3 in. tubes, 4 in. jackets and 4 in. tubes. It should be noted that the actual charges heated average about 22,000 pounds the weight in the sections varying widely, whereas the original estimates were based on charges of 16,000 pounds, approximately uniformly distributed in the sections.

The curves show that for 4 in. tubes, sections 1 and 3 reach temperatures on the surface in 4 hours, section 2 in 3¼ hours, section 4 in 4¾ hours, making an average of 4 hours. This is almost exactly the estimated time for this weight of charge, which is 4.6 hours for the charge to reach temperature throughout.

Similarly for 4 in. jackets the average time would be 4.2 hours. The extreme time of 5 hours in section 4 being required on account of the concentration of weight in the breech of jacket, and also owing to the fact that the charge consists of only three pieces, presenting comparatively little surface through which heat can be absorbed. This is further emphasized by the curve for 4 in. tubes, which, although being a heavier charge, are heated more quickly with less power, and with a very marked increase in pounds per Kw.H. This is due to the greater surface presented by seven pieces.

Fig. 8 also shows the time required for a charge of 12-3 in. tubes. These tubes are practically the same size for their entire length, but do not reach to section 4. They are supported by a heavy fixture in section No. 1. These conditions are emphasized by the curve, which gives 5½ hours, 4 hours, and 2½ hours for sections 1, 2, 3 and 4 respectively. This, and the curve for 3 in. jackets on next sketch represent extreme conditions of unequal loading. These conditions can be largely overcome by lowering the charges in the furnace, in order to put more work in the lower sections. This may be accomplished by lengthening the suspending shafts five feet and the dotted curves on Fig. 8 show the estimated effect of such lowering. Fig. 9 shows the present location of charges in the furnace and the proposed location of 3 in. jackets and 3 in. tubes, 5 feet lower in the furnaces.

Fig. 10 shows curves of draw in furnaces No. 1 and No. 4. Note that these curves cross. This same phenomenon is shown on Figs. 11 and 12 and is accounted for by a serious defect in the heat insulation in furnace No. 1.

Fig. 12 shows the minimum input to the various furnaces by section, which if added will give the radiation losses of each.

A very marked improvement in the operating cycle was noted from this change of lowering charge in furnace both in time and Kw. H. consumption.

The furnaces were guaranteed to operate an economy of not less than eight pounds per Kw. H. The tests give 10.4 to 11.85 pounds per Kw. H.; depending on the distribution of charge in the sections, and the proportion of weight to surface in the pieces charged. The above is for 3 in. tubes, 4 in. tubes and 4 in. jackets, the 3 in. jackets representing such an extreme condition of unequal loading that no comparison is possible with the original estimate.

In regard to the time of heating, it may be said that the conditions have been adequately met, as the estimate of time covered one condition only, namely; uniform load in all sections, and the furnaces did unquestionably meet this condition.

The various test runs have been plotted against one another to make sure that the furnaces are duplicated. Cut No. 13 shows Kw. H. consumed in each section for three hard-

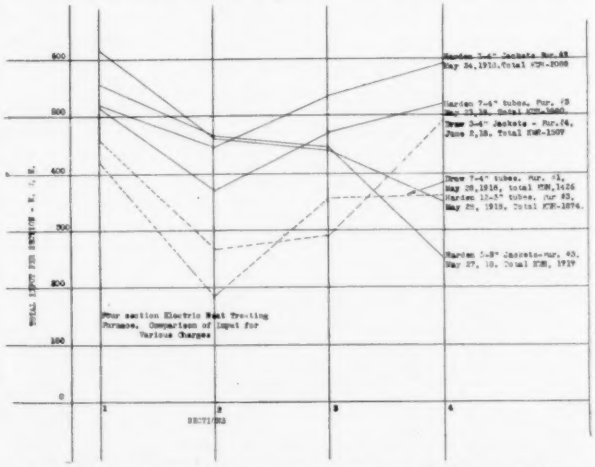


FIG. 11. COMPARISON OF INPUT FOR VARIOUS CHARGES

ening heats of 4 in. tubes, all these taken in different furnaces. Note the curves for furnaces No. 2 and No. 3 are exactly parallel, but furnace No. 2 had not run quite so long as furnace No. 3. If the length of run had been equal the curves would have been exactly superimposed.

The run of Furnace No. 1, however, shows a greater Kw. H. consumption and the curve is not parallel to the other. This leads to the conclusion that there is a crack or other defect in heat insulation of furnace No. 1. This same peculiarity is shown on cuts 16 and 17, and also in the watt meter reading and temperature of casing in the test data, due to distortion of columns and channels embedded into heat insulation.

ELECTRIC SPARKING IN MINES FROM LIGHTNING.

By GEORGE S. RICE and L. C. ILSLEY.

A REMARKABLE explosion of fire-damp caused by a discharge of lightning at the new shaft at the Sitalpur coal mine, has been reported by the Chief Inspector of Mines of India, who gave the following details:

"The explosion occurred during a thunderstorm, and the evidence showed that a flash of lightning had, to all appearances, passed down the shaft causing disruptive discharges at certain points between the guides and the winding rope, rending the latter at two places situated respectively 228 feet and 278 feet from the surface. The distance between the winding rope and the side of the shaft was 5 feet 4 inches, indicating a spark gap of this width, and an intensity of discharge which could not fail to ignite the explosive mixture of gas and air known to be present in the shaft."

The *Compressed Air Magazine*, January, 1920 issue, which contained the above extract also goes on to state:

"In 1915, M. Ferey described before the Societe de l'Industrie Minerale phenomena of a similar character to the above. In a pit liable to sudden outbursts of gas, for the sake of safety, shot-firing was carried out from the surface. During a storm, in the year 1905, shots went off in two places after the detonators had been connected to the conductors, we read in the *Colliery Guardian*, London. These shots were situated respectively 1,400 and 1,410 meters from the firing station. Realizing the possible danger from this cause, the precaution was taken to cut the conductors at the bottom of the shaft and to connect them just before firing. Even under these conditions a shot went off spontaneously, owing, it is believed, to lightning."

The Bureau of Mines, when it was investigating shot-firing from the surface some years ago, found a number of cases where lightning had entered underground. In one case in a shallow mine in Pennsylvania lightning entered following the roots of a tree and caused the death of a man in the main entry. In another case, in the Pratt City Mine which came

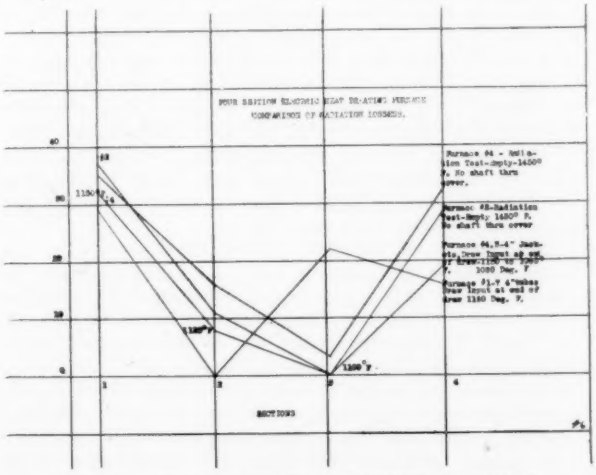


FIG. 12. MINIMUM INPUT TO VARIOUS FURNACES BY SECTION

under the observation of the Chief Mining Engineer, lightning entering on shot-firing wires caused premature ignition and this led to the recommendation of making a gap of about 5 feet in the shot-firing line which was not to be closed by the flexible cable until the men had all been withdrawn from the mine.

Another case reported was that of a mine temporarily abandoned, belonging to the United States Coal and Coke Company at Gary, West Virginia, where an explosion blew up following a flash of lightning which evidently entered the shaft and ignited the fire-damp. The question of providing an arrangement to prevent lightning entering into mines is a difficult one, in mines where electric shot firing on an extension scale is used. The ordinary types of lightning arresters are satisfactory protection against static electric currents produced by lightning discharges, but if a "lightning bolt" actually hits the circuit, there is such an enormous amount of energy to be dissipated that the ordinary devices do not suffice.

Following out the same reasoning, a gap of sufficient length

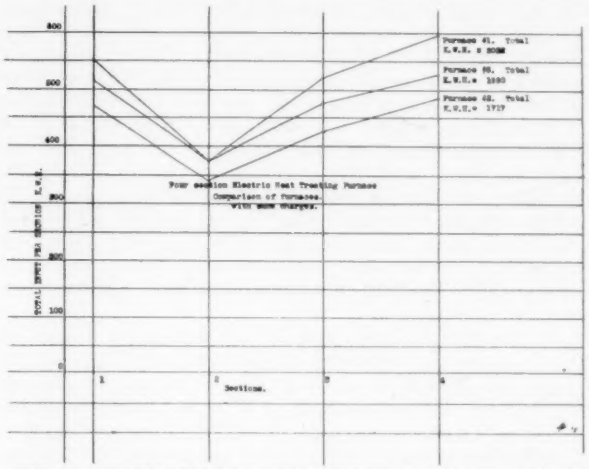


FIG. 13. COMPARISON OF FURNACES WITH SAME CHARGES

to afford protection for static electric discharges resulting from electric storms would not necessarily be a proper protection if the circuit were hit by a "lightning bolt."

There would seem to be need of still greater precautions than are suggested in the following paragraph from Technical Paper 108, Bureau of Mines:

"A suitable gap may be provided by inserting in each side of the circuit, near the bottom of the shaft or the slope, or about 100 feet in by from the mouth of the drift, a flexible conductor about 6 feet long. Each of these conductors can be permanently joined to the end of one of the solid incoming conductors and the other end of each flexible conductor can be provided with a lug for fastening to one of a pair of screw studs in which the outcoming solid conductors should terminate. A similar pair of dummy studs should be installed 6 feet distant from the live studs so as to provide a place for fastening the flexible conductors out of circuit. The dummy studs should be provided with a locked clamp or similar device for locking the flexible conductors out of circuit."

It might be feasible to so arrange a firing circuit that the incoming lines could be connected to a high resistance ground at the same time a gap was made in the circuit. Such a ground would tend to dissipate extraordinary discharges and to prevent such discharges from bridging or jumping the gap in the firing lines.

Again, it might be possible to so arrange the ground, the gap and the direction of the incoming and outgoing shot-firing lines with reference to the gap that the direction of the circuit to the ground is a straight line, while the direction of the circuit through the outgoing lines trough the gap makes a right angle turn. Since lightning tends to follow straight lines this arrangement would probably be an added safeguard.

Finally, care should be taken that all metallic circuits, such as pipe lines of other power circuits entering the mine, are kept at a proper distance from shot-firing lines in order that they shall not serve as possible paths for lightning discharge. If such precautions are not taken it is conceivable that a lightning discharge in a mine through a metallic circuit which is close to a shot-firing line may be partly discharged to the shot-firing lines at a point beyond the lightning gap.—U. S. Bureau of Mines, Reports of Investigations.

Geometrical Form of Rivers*

New Light on the Design of Spur Dikes

THE theory of the free flow of rivers in changing beds seems now fairly established, at least in regard to a few of its parts. The shape of the bed is one of these. In France this theory has received a decisive impulse through the work done by L. Fargue, Inspector General of Bridges and Highways, at the beginning of the last quarter of the 20th century. It is true that even before that time the influence exerted by the shape of the bed, both in plan and in profile, on its depth had been recognized. But it is impossible to find in what had previously been published a general theory for the determination of the best design.

Mr. Fargue's work has been carried on by many other engineers, of which we shall only name Mr. Girardon, whose report, presented in 1894 before the Navigation Congress at the Hague, marks a decisive step forward in the solution of the problem. This report shows in what measure it is possible to apply in practice Mr. Fargue's theory to water streams, as they occur in nature.

All these investigations have led to the fixing of a standard limit-form which rivers with changing beds must approach as closely as possible in order to possess stability, navigable depth and to be able to take care of floods. These conditions are by no means irreconcilable. The first to be considered is stability, without which the others could not obtain. The following gives the definition of this standard type, in geometrical form, as it were.

In the accompanying diagram Fig. 1, the contour lines[1] at the low water bank, marked elevation 0, follow continuous curves resembling the Sine Curve. At one and the same bank they change from concave to convex, and vice versa, the opposite bank going through the same changes in reverse sequence, for the same cross sections taken at right angles to the center line of the channel. The distance between the two curves undergoes a slight periodical variation. They diverge from the point of inflection toward the apex. The distance between them further increases continuously, in a still lesser degree, as they proceed down stream.

These lines are the directrices of, so to speak, ruled surfaces, whose generating lines, at right angle to the directrices, flatten out more and more as they approach the apices of the convexities, and on the other hand become more erect between the points of inflection and the apices of the concavities.

The curved line of intersection of these two surfaces, each belonging to one of the banks, is the center line of the channel. In plan this curve clearly runs close to the concavities and crosses the center line between low water banks, passing from one to the other.

The contour lines, or lines of surface filaments thus generated, also resemble the Sine Curve and are similar to the directrices taken at the low water banks. In horizontal projection they converge at the concave banks and diverge at the convex banks. Lines of same elevation on each bank converge, the more closely the lower this elevation. Near the point of inflection they come in contact at the center line of the bed. The curves of lower elevation than the contact lines close and form crescent shaped pockets at the concavities.

Above the directrices chosen (low water banks) the generating lines increase in length by an increment continuously decreasing as one proceeds from the convex to the concave apex. The locus of the extreme end of these generating lines is the foot of the river bank, consisting of a rather steep slope which limits the river bed, generally in a firmer part of the soil. Proceeding from a convexity to a concavity this slope—one bank only being considered at a time—converges toward the directrix, and its height may vary between the extreme limits of zero to the height of the valley level above the low water bank. The slopes of the two opposite banks run gradually farther apart as one proceeds from the points of inflection toward the apices, for the reason that the width gained at the convex bank is greater than the width lost on the concave side.

Mr. Fargue in his two essays published in the Annales des Ponts et Chausseés[2] has indicated the numeric proportions which these elements must satisfy in order to produce best results. In first place they establish the relation of the width at the points of inflection to the width at the apices, and of these widths to the distance from points of inflection to the apices, and finally, of these distances to the angles enclosed between the tangents at two consecutive points of inflection. It is needless to give here all these data. Suffice to say that they have been computed, that they are theoretically interesting and that it would be worth while to confirm them by calculations based on the principles of hydraulics. For Mr. Fargue has deduced them from observations only, and these have been limited in number. They are, however, sufficient to establish the fact that there is an ideal best type, and further to establish the general aspect of this type.

It would be difficult to recognize in this geometric picture a river in its natural or even considerably regulated state. The resemblance is about as close as that of a mountain peak and a pyramid or a cone. This, however, is the inevitable shortcoming of any attempt to represent by means of geometry or calculation objects and phenomena as they occur in nature. Nevertheless, in many cases even such imperfect representations are useful. The conception of a standard type, geometrically defined, may serve as a guide for the regulation of a river, although the latter could never be made to resemble it very closly.

In fact if we examine the various regulation systems proposed or executed since the above theory was formulated, we shall find that all of them, implicity or explicitly, are nothing more than the application of the appropriate means to make the stream under consideration resemble as closely as possible the standard type, as seen by the designer. However, as it is impossible in the majority of the cases to obtain this result for the whole of the river, the regulation is attempted in sections only and often limited to the crossings at the points of inflection. One of the main points of Mr. Girardon's report is precisely the stating of this very fact.

The means of attaining the desired form are many. Mr. Fargue seems to admit that by fixing the banks, especially the concave bank, according to an appropriate design, the standard form will automatically be realized. He supports this statement with favorable examples, but we believe these to be due to fortunate circumstances, first among these the fact that the course of the center line, in plan, varies little from the theoretical course, especially so in regard to the distances between apices of the curves and their relation to the angles they enclose. When, as this is the case for the Seine River, these distances are excessive and include long straight alignments their design presents peculiar problems and the construction of high dikes is not sufficient for their regulation, except where a narrowing of the bed is useful.

Some time the directrix (line of the low water bank) or a neighboring water line is fixed instead of the high river bank. This is the system of the low training dikes.

High dikes and low dikes used separately having sometimes proved insufficient, they have been combined, fixing the form of the bed by two directrices on each bank.

Again, along another line of thought, generating lines of

[1]Upon a sufficiently reduced length, these two kinds of curves, which differ in principle, because of the slope, practically merge.

[2]Fasc. II, 1903: Form of the Bed of Navigable Rivers, and fasc. III, 1907: Equations of the Empirical Laws of Fluvial Hydraulics (both in French).

the standard form have been fixed instead of directrices. This is the system of the dipping spur dikes, submerged dikes, etc., as applied on the Rhône River.

Both systems, longitudinal and cross dikes, have been combined in various ways on the Rhône and later on the Loire. On the Rhône T-shaped dikes have been built which are elements of generating lines combined with elements of low directrices. On the Seine spur dikes were attached to high dikes, or a high dike was connected to a low dike by a few cross dikes. In short parts of the two groups which we just have outlined were fixed in a haphazard way, without a well defined plan and therefore without the necessary elements of success.

Approached with this broader view, the study of the regulation opens a vista on new variations.

Why limit to two the number of dikes, high dike and low dike (Fig. 2) and thus substitute for the normally gentle slope of the convex bank two very high steps? Would it not be more natural to multiply the number of steps and follow more closely the straight course of the generating line? Where conditions favor the formation of deposits back of each elementary dike this system has the advantage of great saving in material (Fig. 3). Dikes arranged in successive steps would follow the horizontal projection of the stream lines. They would have their maximum spacing at the apex of the convexities and converge gradually so as to unite in one single dike at the apex of the concavities. The banks would be ascended in steps like stairs in a house.

Nothing would prevent the crossing of the longitudinal dikes by cross dikes dropping from the elevation of one to that of another and being arranged like cross hatching on a topographical map between contour lines.

The number of possible combinations is unlimited. Once the principle from which they are derived is well understood they present themselves to the imagination. Therefore we shall, in conclusion, only insist on this principle. Properly to design the regulation of a portion of a river it is well to have in mind the scheme of the normal shape of its bed and its decomposition into curved directrices and straight generating lines. The regulation will consist in the creation of a skeleton made up of directrices and generating lines, resembling as closely as possible the standard form and arranged in such a way as to fill out with silt deposits following this form, and to reduce the necessary construction work to a minimum.

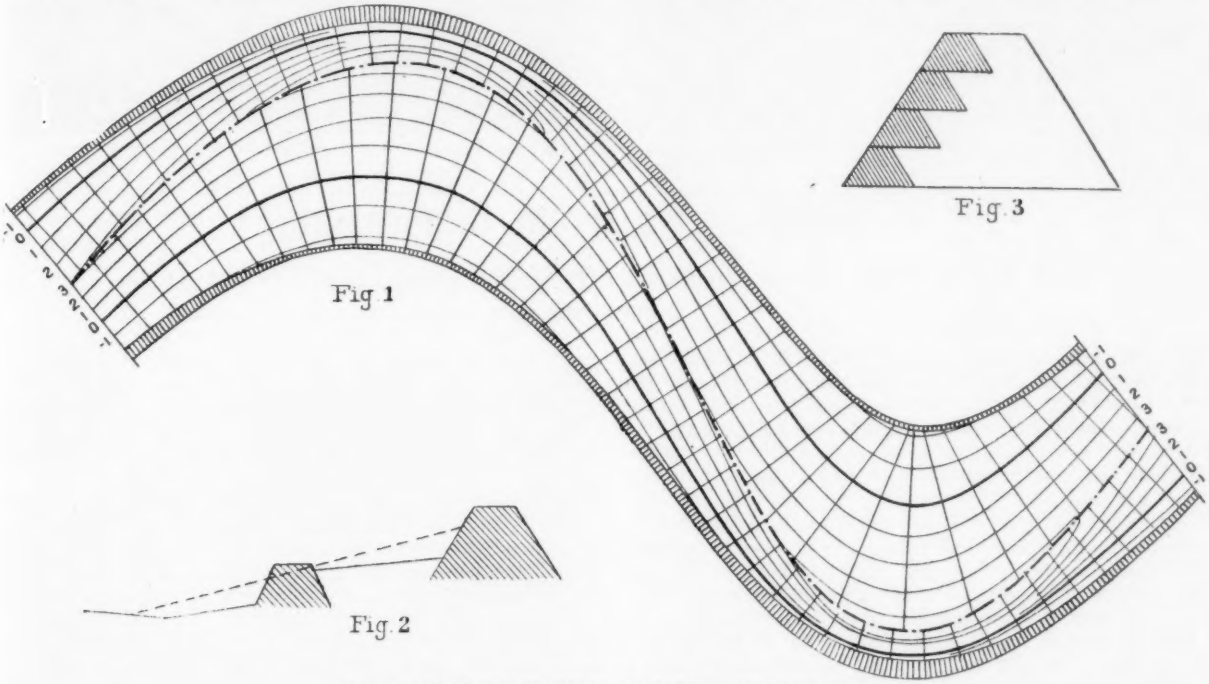


Fig. 1

Fig. 3

Fig. 2

IDEAL GEOMETRICAL FORM OF A STREAM OF WATER

RESISTANCE TO DECAY NOW A FACTOR IN CHOICE OF AIRPLANE WOOD.

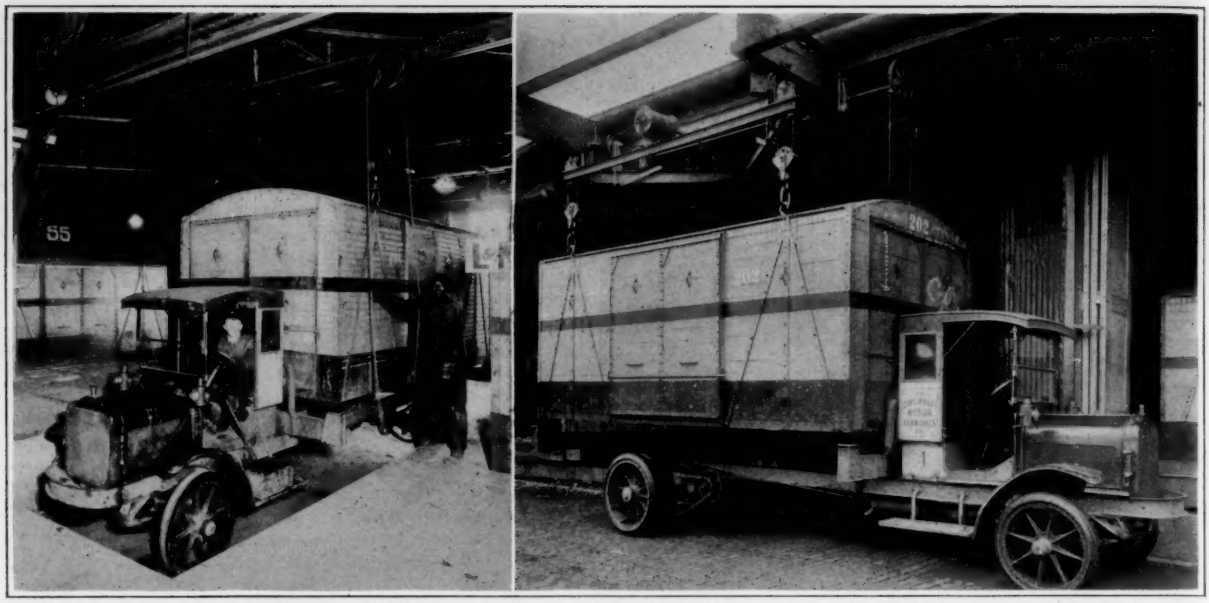
AIRPLANES in the past have been so short-lived that it has mattered little whether the wood in them was resistant to decay or not. Now with better construction and less accidental breakage of airplane parts, instances are coming to the attention of the Forest Products Laboratory of parts needing replacement because of decay.

The fact is being recognized that many woods in common use for airplanes are not resistant to decay and may be destroyed very rapidly when exposed to unfavorable weather conditions.

Fortunately, there are woods whose value in aircraft has been demonstrated which are highly durable. Among these perhaps the most notable is Port Orford cedar. Two others which in tests made by the laboratory have proved very resistant to decay are southern cypress and California redwood. Douglas fir, white oak, and black walnut stand fairly high in durability. Mahogany and Spanish cedar are reputed to be very durable, but no tests have been made on them in the United States. Spruce, which has been the favorite wood for aircraft, is, unfortunately, appreciably less durable than any of the species mentioned. Likewise basswood, beech, birch, and maple may be classed with the less durable species.

The sapwood of practically all species decays readily. Hence in selecting wood for durability, only the heartwood should be accepted.

In cases where it is not practicable to use a naturally durable wood, the life of the wood part may be prolonged by giving it a preservative treatment. Sodium fluoride is a preservative which may be successfully used on parts that are to be glued. Coal-tar creosote, where its color and odor would not be objectionable, may be used for parts that are not to be glued. Decay in struts, propellers and some other large members can be prevented by applying a coating of aluminum leaf. This keeps the wood dry and dry wood does not decay.



TROLLEY FOR CONVEYING DEMOUNTABLE BODY TO A TRUCK CHASSIS (LEFT) AND REMOVING THE BODY FROM THE TRUCK (RIGHT)

Motorizing Railroad Terminals*

The Use of Motor Trucks to Release Box Cars Held Up at Freight Yards

By B. F. Fitch

FOR years trucks have been proven valuable transportation mediums, but their adoption and scientific operation has been ignored by railroads whose business was primarily transportation. This was possibly due to the fear of competing service similar to the old theory a couple of decades ago that interurban lines would detract from railroad earnings.

The ingredients to be considered in transportation cost estimates are tons, miles and minutes, and, generally speaking, the greater number of tons and miles, crowded into the smallest number of minutes, the lower the transportation cost.

Every unit of transportation from wheel-barrows to gondolas is valuable when allotted exclusively to the service it is best fitted to discharge. A team can successfully haul 75 ton-miles and a motor truck 500 ton-miles in a ten-hour working day. Compare this with railroad performance in which the average box car movement is but 25 miles per day. If loaded with merchandise to but a ten-ton average, it discharges but 225 ton-miles in a 24-hour day. It is therefore, obvious that box cars suffer a handicap.

Freight house operating practice demands that box cars lie idle ten hours a day. If utilized exclusively for transportation and kept continuously moving for the remaining fourteen hours, even at an average speed of but twenty miles per hour with ten-ton loads, the potential possibility of each freight car is 2,800 ton-miles daily.

There is practically no limit to what the rails will carry, if cars, when consolidated in trains, are at once started and kept continuously moving; therefore, it is logical to charge inadequate terminal facilities with the major portion of the box car's tonnage deficiencies. Inadequate terminals alone are not responsible for this nor can either the railroads or the public be censured for illegitimately using box cars in lieu of other facilities for short term storage. These are influences detrimental to box car efficiency, but without terminals, necessary evils.

The prime trouble is that, as an operating necessity, in absence of other facilities, box cars have been assigned to a service for which they were never originally intended, and this make-shift usage has complicated switching interchanges at all terminal points to the detriment of high mileage efficiency of all cars.

Our national transportation practice and trade influences of the traffic do not permit of any radical terminal changes. Any revolutionary attempts along this line might embarrass our production resources as greatly as a change in the monetary basis. Therefore, evolutionary improvements only can be considered.

Refinements of present rail practice and additional facilities will occur, but rail transportation cannot be greatly improved because locomotives are now practically up to the safety limits of rails and bridges and without increasing weight of locomotives, draw bar efficiency cannot be increased, and without an increase in draw bar efficiency transportation costs cannot be lowered. Thus, obviously the field for improvement is terminals.

To demonstrate the fact that railroad transportation has outgrown railroad terminals, it is interesting to note that from outer classification yards to pier station delivery at New York the cost to carrier is not less than $3.50 per ton and, similarly, at Philadelphia not less than $2.50 per ton, or a joint terminal cost of $6 per ton. Whereas, the main line haul between these two terminals, if estimated at a maximum cost of 6 mills per ton-mile, suggests a transportation cost of 60 cents versus terminal costs of $6. Chicago is no better off than Philadelphia and the haul is about ten times as long; hence, joint terminal cost is as great as the transportation or rail haul cost from Chicago to New York.

After five years of terminal studies, inspecting innumerable stations built over fifty years ago which are still the intakes and outlets of our great transportation systems, using the recognized best equipment in the world, no wonder the subject of terminals is a topic of nation-wide discussion and, naturally, all with creative brains are offering solutions.

*Paper read at the convention of the Materials Handling Machinery Manufacturers' Association, New York, Feb. 26, 1920.

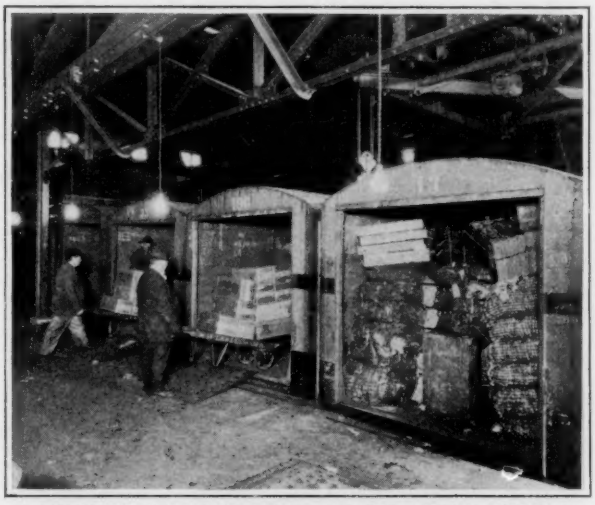
With unlimited financial resources the engineering talent of this country can quickly solve the problem. Ideal joint terminals at a cost of $50,000,000 to $500,000,000 are possible in all of our principal centers, but present chaotic conditions considered who will assume the responsibility of such abnormal financing? Even if offered opportunity to avail themselves of such the railroads would have to scrap present huge investments and the scrapping of these investments at any industrial center will disrupt realty values possibly to financial ruin of innumerable manufacturing plants built in suburban localities on the theory that the inducement which warranted the building would afford perpetual service.

For this reason each present terminal layout must be continued substantially as at present. Conservatism recommends no radical changes, but demands revolutionary changes to better conditions for both carriers and shippers.

Every city in the country has its labyrinth of rails, team tracks, private sidings, obsolete main freight stations and sub-stations, between all of which box cars are shuffled or switched around, like cards in a solitaire deck, in the performance of a duty for which the cars were never designed.

The innumerable switch cut movements of such cars confiscates capacity of the rails and the cost of handling these cars over rails, to detriment of through traffic, is primarily responsible for excessive terminal expense.

If all the large cities in the country could be furnished with ideal scientifically designed and mechanically operated freight houses, there is no question of accruing economies both in terminal practice and transportation costs, because the railroads then would enjoy a one point make-up and a one point break of all freight cars. The result would be loading of cars to weight or displacement capacity for uninterrupted direct movement to other terminals. This consolidated loading would naturally decrease the number of cars now dispatched from a plurality of stations within any one city to the existing plurality of stations in all other cities.

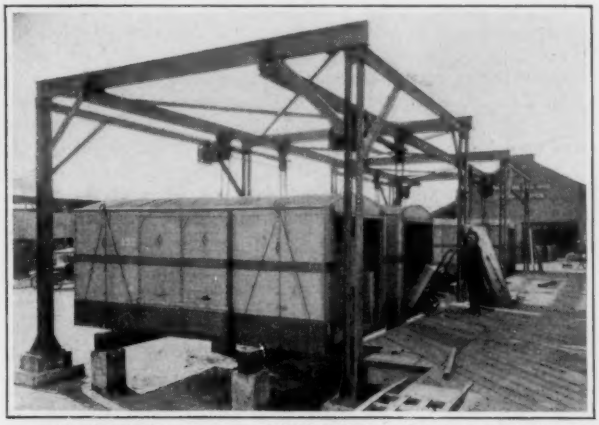


DEMOUNTABLE BODIES BEING LOADED AT THE FREIGHT HOUSE OF THE LOUISVILLE & NASHVILLE RAILROAD AT CINCINNATI

Despite this opportunity, even if attainable, the industrial trap car and the intro-terminal trap car will apparently always complicate terminal interchanges to detriment of switching refinements. Terminal operating economies will be in direct ratio with the decrease in the number of interchange switching combinations. So apparently new freight stations at huge investment are no guarantee of great reductions in terminal expense, because freight station labor cost is but a small item as compared with total terminal expense.

Between all the widely distributed freight houses of the various railroads in each and every terminal, box cars are used in transfer or connecting line service. When so used, they are in various sections termed "trap," "transfer" or "ferry" cars. For instance, in any city with seven non-competing railroads radiating to different sections, each line receives daily in its city cars some freight for each of the city connections. Numerically this means 42 cars in transit to and 42 cars in transit from, a total of 84 cars. But due to yard interchange delays these cars average a third day arrival instead of a second day arrival; hence, 252 cars are assigned daily to such service. Thus 75,600 car days are required annually.

Industrial expansion at any city with seven initial lines,



SUB-STATION OF THE BALTIMORE & OHIO RAILROAD, CINCINNATI, SHOWING DEMOUNTABLE BODIES BEING LOADED AND UNLOADED

has, as a rule, outgrown station facilities and railroads for economy's sake have strategically established sub-stations along their rights-or-way as traffic influences for shipments from outlying districts. Since all the freight from these outlying districts has to be brought to main stations to be consolidated in cars for dispatch from such main stations to destination points, and since all of the freight for these sub-stations comes out of main station cars on arrival, trap cars are necessary in this main sub-station service of each line. The number of cars so used is a multiple of stations. If, as above stated, each of the seven lines has three stations, 42 cars are required, movement delays to which are as great as connecting line cars; therefore, the wasting of an additional 37,800 car days. This explains one of the reasons for car shortage and an operating abuse which has been obsoleted by the success of a motor terminals installation at Cincinnati, Ohio.

Briefly, this installation consists of overhead rails, electric cranes, electric hoists, motor trucks and a plurality of interchangeable motor truck bodies. The system of operation requires an empty body for each station movement demand of railroad on its inbound main station platform. At the larger stations there are several locations for such body settings, thereby decreasing the trucking distance for freight. As the freight comes from the cars, it is trucked to the nearest location containing a body carded for any connection or any sub-station.

When loaded, these bodies are sealed and under telephone order of a joint dispatcher, employed by the railroads, mechanically loaded upon trucks and thus routed over city's streets to connection.

On arrival at outbound platform of the connecting line, the body is mechanically removed and an empty body, previously unloaded, is similarly put upon motor truck chassis for delivery to inbound platform of that house, where the operation is repeated and another loaded body forwarded in the same manner to some other freight house.

If the load happens to be to a sub-station, it remains on

platform until dispatcher is advised by agent at sub-station that return load is available. Then the loaded body of inbound freight to that substation is forwarded and the motor truck exchanges same for the previously reported load of outbound freight to be delivered at main station, where it is consolidated with other city freight in line cars made up daily to innumerable other destination points.

From the above it is evident that all freight, except possibly the portion arriving during the last hour of station operating day, whether between main and sub-stations or between main stations of the various railroads, is currently loaded and out of the terminal. Previously this freight by trap cars suffered an average three days' delay and the shuttle movement of these individual cars over terminal rails interfered with the group movement of complete cuts of station cars. Hence, the congestion which previously made Cincinnati notorious as a check-valve in rail routings.

In May, 1917, the Big Four Railroad permitted a test installation between its five main and sub-stations. The innovation was an early success, but the other roads were skeptical of its enduring efficiency. In the early months of 1918 a special committee was appointed to analyze the entire terminal and, based upon Big Four accomplishments, recommend what economies and benefits could be anticipated from completely motorizing Cincinnati's terminal.

The summary of this comparative report prophesied the following, and as a result contracts were negotiated:

Annual economy, $61,652.96;

Advance movement of freight 52.4 hours;

Increase inbound platform floor area 14.8 per cent;

Increase outbound platform floor area in ratio with station operation;

Increase main station trackage 21.4 per cent;

Increase main station realty 122,660 square feet;

Release 66,862.5 cars for line service per annum;

Extension of present labor, 30.4 per cent;

Eliminating the rehandling of 86,976 tons of freight, lessens railroads' liability of loss and damage.

In 1919 equipment orders were entered and railroads commenced station changes and superstructure construction. The terminal is not fully equipped, for both the railroads and the Cincinnati Motor Terminals Company which is operating this equipment on contract basis for the railroads, has suffered exasperating delays. However, in recent analyses of accomplishments it is proven that, owing to increased operating costs of railroads the prophesied 17.1 cents per ton economy is in practice actually a saving of 35.2 cents per ton, making the annual economies $126,507.75 instead of $61,652.46.

This service has proven that all widely distributed station facilities can be laced up as a unit without investment cost to the railroads, thereby giving to each and every terminal the benefits of a union freight station. The rates paid for the service are less than what interest charges alone would be on the cost of constructing a consolidated terminal. The operating program of railroads and the established perquisites of shippers are in no wise disturbed, but the railroads at large through the influence of this current versus their past interrupted movements enjoy an increase of terminal rail, station rail, and station platform facilities. This increase can be perpetually extended at minimum investment, in ratio with increasing tonnage demands, which naturally will accrue at any industrial city enjoying better shipping facilities.

Extensions are now possible in the form of rail sub-stations or off-track warehouse sub-stations by this system, and can be gradually provided when tonnage demands warrant. There is no necessity to finance elaborate facilities to take care of accruing demands which may not develop for fifty years.

What has been done at Cincinnati can be adapted to the varying demands of all principal terminal cities. In some the connecting line trap car predominates as the greatest detriment to successful terminal operation; in others the sub-station trap car.

The flexible possibilities of trucks are now clearly defined for industries whose transportation facilities are dependent upon rail extensions. Opportunities at each point are limited only to intelligent installations following detail analysis to establish the greatest terminal deficiencies of carrier to meet shipping demands of the public.

Acomplishments at Cincinnati warrant idealistic theories of the system as applied to the greatest terminal problem in the world. New York is that problem, for as the established principal port of this country, our industrial expansion is restricted by New York's lack of port facilities, unless, as will ultimately happen, the nation at large refuses longer to suffer by reason of New York's conservatism and creates other trans-shipments ports.

At present the railroads monopolize approximately 30 per cent of Manhattan's piers for freight stations. To expand the port these piers are indispensable for coastwise and overseas steamers. Where not individually owned, the rental value of piers is out of all proportion with freight tariff returns.

A few blocks inland, realty enjoys but a fraction of bulkhead rental values. If inland joint stations in say 12 zones were constructed on this otherwise comparatively non-productive realty, the railroad piers could be released for shipping and station facilities be attained by the railroads at practically no cost, because of increased rentals possible from warehouses and industrial floors above joint freight terminals.

If all roads contributing this terminal had transfer stations at their rail bulkheads or a few blocks back from the Jersey, Staten Island and Bronx valuable waterfront, carload and less carload package freight could be immediately transferred from cars to motor truck bodies, which would be designated for each of these inland stations, and the freight cars thereby released for immediate reloading of outbound freight. The number of bodies assigned each zone station would be sufficient to meet the tonnage demands.

These bodies when loaded on trucks, would be routed over streets to nearest available Staten Island or Jersey slip for ferrying to Manhattan slip nearest inland station destination and vice versa on return movement. Until they were proven inadequate, public ferries could be used.

If we add to the generally admitted $3.50 terminal cost to carriers the established minimum cartage cost of $2.50 per ton to shippers, the joint terminal cost at New York is $6.00. Under normal conditions approximately 30,000 tons daily moves from State Island and Jersey to Manhattan and 20,000 tons daily from Manhattan to Staten Island and Jersey on outbound movement, a total of 50,000 tons daily, which at the above cited $6.00 joint cost is an item of $300,000 per day.

For the railroads alone at Cincinnati the interchange is furnished by the Cincinnati Motor Terminals Company between stations within a ten-mile zone at rates averaging less than $1.00 per ton. The minimum is 80 cents and the maximum $1.25. If trucks moved by short ferry routes (at no operating cost in ferry transit other than ferry tariffs) no hauls from rail bulkhead transfer platforms to inland stations could exceed ten miles.

It is impossible to prophesy what rates for this interchange can be established, but they would certainly not be over $2.00 per ton. Owing to the short haul afforded shippers by these inland stations and the unlimited tail gate space, which they would enjoy at such, the cost to shippers could not average over $1.00 per ton. Hence it is logical to infer a joint net saving of $3.00 per ton is possible for 50,000 tons daily, an annual item of $45,000,000. No wonder the high cost of living on Manhattan! But one year's savings will more than cover the entire necessary outlay if the cost of inland stations is not considered.

The inland station investment is a realty venture requiring no financing on the part of the railroads, because assured rental returns from upper stories will invite outside capital to furnish the station facilities in ever increasing numbers as fast as the railroads desire to contract for the use of such.

The Last Stand of the Reciprocating Steam Engine*

Startling Picture of the Inefficiency of the Steam Locomotive

By A. H. Armstrong

DURING the year 1920 the people of the United States will pay out for automobiles, not commercial trucks nor farm tractors, but pleasure vehicles, a sum of money considerably greater than the estimated requirements of our steam railways for that year. The railways, however, may find it very difficult and perhaps impossible to secure the large sums needed without government aid, notwithstanding the fact that the continued operation and expansion of our roads is of vital necessity to the welfare and prosperity of the country and all its industries. The will of the American public has always been constructive and undoubtedly, in due time, its voice will be heard and properly interpreted by its representatives in Washington with the resulting enactment of such laws as will permit our railways again to offer an attractive field for the investment of private capital.

The purpose of this paper is not to discuss the politics of the situation nor any necessary increase in freight rates that may be required to make our roads self-sustaining, but rather to offer certain suggestions as to the best manner of spending the sums that must ultimately be provided for new construction and replacements.

During the war period many lessons have been most clearly brought home to us and not the least of these is that there is something inherently wrong with our steam railroads. During the three generations of its development, we have become accustomed to look upon the steam engine as properly belonging to the railway picture and have given little thought to its wastefulness and limitations. It is around the steam locomotive that railway practice of today has gradually crystallized.

During the winter of 1917-18 our railways fell down badly when the need for them was the greatest in their history. It is true that the cold weather conditions were unprecedented and the volume of traffic abnormal, but the weaknesses of steam engine haulage were disclosed in a most startling and disastrous manner. Delayed passenger trains in cold weather can be endured by the traveling public in suffering silence or voluble expression, according to temperament; but the blocking of our tracks with frozen engines and trains, resulting in a serious reduction of tonnage in cold weather and a prohibitive delay in transportation of freight in times of great stress, is quite another thing and plainly indicates the inability of the steam engine to meet overloads and adverse climatic conditions.

In marked contrast to the adjoining steam engine divisions, the 440-mile electrified section of the Chicago, Milwaukee and St. Paul Railway continued to do business as usual all through that trying winter of 1917-18. The electric locomotives brought both freight and passenger trains over the electrified tracks in schedule time or better; in fact, it was quite customary to make up on the 440-mile electric run fully two hours of the time lost by passenger trains on adjoining steam engine divisions. While the results obtained upon the Chicago, Milwaukee & St. Paul were perhaps more spectacular due to the greater mileage electrically equipped, other electrified roads contributed similarly attractive records. The reliability and permanency of the comparison between steam and electric locomotive haulage is sufficiently guaranteed, therefore, by the results of several years' operation, to justify drawing certain conclusions regarding the merits of the two types of motive power. The following analysis of the railway situation is therefore offered for the purpose of exposing the fact that railroading today is in reality steam engine railroading and the general introduction of the electric locomotive will permit of fundamental and far reaching changes in the method and cost of hauling freight and passenger trains.

The writer is not proposing the immediate electrification of all the railways in the United States, as many roads of lean tonnage would render no adequate return upon the large capital investment required, but is offering the following table of total operating statistics simply as a measure of the magnitude of the problem confronting us in the future. In this country it should be noted, however, that we have during the past thirty years installed electric power stations equal to twice the estimated capacity required for the electrical operation of every mile of our tracks today.

TABLE I—TOTAL TON-MILE MOVEMENT ALL RAILWAYS IN UNITED STATES—YEAR 1918.

	Per Cent	Ton Miles
1—Miscellaneous freight cars and contents	42.3	515,000,000,000
2—Revenue coal cars and contents	16.23	197,000,000,000
3—Locomotive revenue, driver wt. only	10.90	132,300,000,000
4—Passenger cars, all classes	16.13	196,000,000,000
Total revenue, freight and passenger	85.56	1,040,300,000,000
5—Railway coal	5.00	60,600,000,000
6—Tenders, all classes	6.50	78,800,000,000
7—Locomotive railway coal	0.39	4,700,000,000
8—Locomotive, non-driving wt.	2.55	31,000,000,000
Total non-revenue	14.44	175,100,000,000
GRAND TOTAL (All classes)	100	1,215,400,000,000

The tonnage passing over the tracks of our railways may be subdivided in a most interesting manner as shown in Table I. The first four items, representing 85.56 per cent of the total ton-miles made during the year 1918, may be regarded as fundamentally common to both steam and electric operation. By introducing the electric locomotive, however, the last four items are reduced to the extent of completely eliminating items (6) and (7), reducing item (5) by possibly 80 per cent and item (8) by one-half. Of the total of 14.44 per cent affected, therefore, it may be assumed for purposes of comparison that approximately 12 per cent or 146,000,000,000 ton-miles at present hauled by steam engines over our roads will be totally eliminated with electric locomotive haulage. This ton-mileage eliminated is equal to over 20 per cent of items (1) and (2) representing the revenue producing freight traffic on our railways. In other words, if all our railways were completely electrified they could carry one-fifth more revenue producing freight tonnage with no change in present operating expenses or track congestion.

It is evident that the greater part of the tonnage reduction effected by electrification is included in items (5) and (6), representing the railway coal movement in cars and engine tenders. The steam engine tender will of course entirely disappear, while the railway coal haulage will be largely curtailed by utilization of water as a source of power and the establishment of steam power houses as near the coal mines as an abundant supply of good condensing water and load demand will permit. While water power should be utilized to the fullest economical extent, the greater portion of the railway power must undoubtedly be supplied by coal, due to the unequal geographical distribution of water power available.

Even with coal as the source of power, it may not be fully appreciated just how enormous is the saving made by burning fuel in large modern power stations under the most efficient conditions possible, instead of under the boilers of 63,000 en-

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gines which by necessity must be designed and operated for service rather than for fuel economy. During the year 1918 the fuel used by railways is reported to be as shown in Table II.

TABLE II—RAILWAY FUEL 1918.

Total coal production (all grades)	678,211,000 tons
Used by steam railways	163,000,000 tons
Percentage of total	24 per cent
Total oil marketed in U. S.	355,927,000 bbl.
Used by steam railways	45,700,000 bbl.
Percentage of total	5.8 per cent
Coal equivalent of oil at 3½ bbl.	13,000,000 tons
Total equivalent railway coal	176,000,000 tons

A quarter of all the coal mined in the United States is consumed on our railways and the following analysis will point out some features of this extreme wastefulness which are inseparable from steam engine operation.

During the year 1910, exhaustive tests were made upon the Rocky Mountain Division of the C., M. & St. P. Ry. to determine the relation existing between the horse-power-hours work done in moving trains and the coal and water consumed on the steam engines in service. Table III gives the results of these tests:

TABLE III—C., M. & ST. P. RY.; ROCKY MOUNTAIN DIVISION. COAL AND WATER USED.

	Water per H.p.-hr.	Water per Lb. Coal	Coal per H.p.-Hr.
Three Forks-Piedmont	39.6	5.08	7.75
Piedmont-Donald	35.4	4.70	7.54
Deer Lodge-Butte	39.7	4.85	8.31
Butte-Donald	40.4	4.86	8.74
Harlowton-Janny	38.0	4.09	8.90
Janny-Summit	44.2	4.65	9.48
Three Forks-Piedmont	41.4	6.51	6.37
Piedmont-Donald	40.2	5.63	5.78
Average of eight tests	39.86	5.04	7.86

The records were obtained during the portion of the runs that the engines were doing useful work in overcoming train and grade resistance, that is, all standby losses were excluded. The through run, however, included such losses in the magnitude shown in Table IV:

TABLE IV—STANDBY LOSSES.

	Coal per hour
Fire banked in roundhouse	150 lb.
Cleaning fires for starting	800 lb.
Coasting down grade	950 lb.
Standing on passing track	500 lb.

Adding standby losses to the average of 7.86 lb. per h.p.-hr. obtained in the preceding eight tests, the total actual coal consumed under the engine boiler in twenty-four hours divided by the actual work performed by the engine is found to be 10.18 lb. per h.p.-hr. at the driver rims.

As the result of this particular series of tests it was determined that the coal consumed while doing useful work was raised 30 per cent by standby losses. It should be appreciated in this connection moreover that this value was obtained on through runs with no yard switching service or adverse climatic conditions. It may be concluded therefore, that under all conditions of service fully one-third the coal burned on our steam engines today is absolutely wasted in standby losses of the general nature indicated above.

Supplementing these tests, a 30-day record was kept of all coal used on the entire Rocky Mountain Division and the total engine, tender, and train movements reduced to horse-power hours, resulting in a value of 10.53 lb. coal consumed per horse-power-hour at the driver rims. Both the above values were based upon constants of 6 lb. per ton train resistance at all speeds and 0.7 lb. per ton per degree of curvature as determined in part by dynamometer car tests and representative of general railway operation. Reducing the average coal values of the test runs and the 30-day record per horse-power-hour to electrical constants, we arrive at the data shown in Table V:

TABLE V—COAL EQUIVALENT PER KW-HR.; STEAM OPERATION.

Coal per h.p.-hr. at driver rims	10.27 lb.
Coal per kw-hr. at driver rims	13.75 lb.
Coal per kw-hr. at power supply on basis 55 per cent efficiency	7.56 lb.

It is this last figure of 7.56 lb. of coal burned on steam engines to get the equivalent tonnage movement of one kilowatt-hour delivered from an electric power station that is of special interest to this discussion. Comparing coal and electrical records on the Butte, Anaconda & Pacific Railway before and after electrification results in arriving at a value of 7.17 lb. of coal previously burned on the steam engines to equal the same service now performed by one kilowatt-hour input at the substations, a figure comparing favorably with 7.56 lb. above arrived at by an entirely different method.

TABLE VI—ANALYSIS OF ROUNDUP COAL USED.

Fixed carbon	49.26 per cent
Volatile carbon	38.12 per cent
Ash	7.74 per cent
Moisture	4.88 per cent
B.t.u.	11,899

Making due allowance for the fact that roundup coal is somewhat low in heat units, it is nevertheless within the limits of reasonable accuracy to assume that the steam engines operating over all our railways are consuming coal at a rate closely approximating 12.75 lb. per kilowatt-hour of useful work done, as measured at the driver rims or 7 lb. per kilowatt-hour as measured at a power station and including for convenience of comparison the transmission and conversion losses inherent to electrical operation.

An electric kilowatt can be produced for so much less than 7 lb. of coal that we are now in position finally to forecast the approximate extent of the coal economy that would result from electrification.

TABLE VII—RELATION BETWEEN KW-HR. AND TON-MILES, CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY, AVERY-HARLOWTON—YEAR 1918.

	Passenger	Freight
Average weight locomotive	300 ton	284 ton
Locomotive miles, 1918	651,000	1,431,500
Locomotive ton-miles	195,000,000	407,000,000
Trailing ton-miles	434,406,000	2,903,099,000
Total ton-miles	629,406,000	3,310,049,000
Kilowatt-hours	24,890,000	105,287,000
Watthours per ton-mile	39.6	31.9
Ratio locomotive to total	31 per cent	12.3 per cent
Watthours per ton-mile combined movement		33.2
Ratio locomotive to total combined movement		15.25 per cent

All power values in Table VII are given at the point of supply from the Montana Power Company at 100,000 volts and include deductions made for the return of power due to regenerative braking of the electric locomotives on down grades, amounting to approximately 14 per cent of the total. Owing to the excessive rise and fall of the profile of the electrified zone of the C., M. & St. P. Ry., its operation is materially benefited by regenerative electric braking and the value of 32.2 watthours per ton mile for combined and passenger movement should possibly be raised to the round figure of 40 to make it apply more nearly to conditions universally obtaining on more regular profiles.

Hence referring again to the ton-mile values of Table I:

Total ton-miles, 1918	1,215,400,000,000
Watthours ton mile	40
Kw-hr. total movement	48,700,000,000
Coal required at 7 lb. per kw-hr	170,000,000 ton

The actual equivalent coal consumed on our steam railways for the year 1918 is given as 176,000,000 tons, closely approximating the figure of 170,000,000 tons estimated above from the operating results obtained on the C., M. & St. P. electrified zone. These several values check so closely as to justify the completion of the fuel analysis of the railways as shown in Table VIII.

TABLE VIII—COAL SAVING BY ELECTRIFICATION

Total ton-miles steam	1,215,400,000,000
Reduction by electrification	146,000,000,000
Total ton-miles electric	1,069,400,000,000
Kw-hr. electric at 40 watts	42,776,000,000
Coal on basis 2½ lb. per kw-hr.	53,500,000 tons
Equivalent railway coal 1918	176,000,000 tons
Saving by electrification	122,500,000 tons

The startling conclusion arrived at is that approximately 122,500,000 tons of coal, or more than two-thirds the coal now burned in our 63,000 steam engines, would have been saved during the year 1918 had the railways of the United States been completely electrified along lines fully tried out and proved successful today. This vast amount of coal is 50 per cent greater than the pre-war exports of England, and twice the total amount consumed in France for all its railways and industries. Moreover, the estimate is probably too conservative as no allowance has been made for the extensive utilization of water power which can be developed to produce power more cheaply than by coal in many favored localities.

Perhaps no nation can be justly criticized for lavishly using the natural resources with which it may be abundantly provided. In striking contrast with the picture of fuel waste on the railways in this country however is the situation presented in Europe at this writing.

Faced with a staggering war debt, with two millions of its best men gone and an undetermined number incapacitated for hard labor, and with so much reconstruction work to do, France has to contend also with the destruction of half its coal producing capacity. Before the war, France imported twenty-three million of the sixty-five million tons of coal consumed. It is estimated that the full restoration of the coal mines in the Lens region will take ten years to accomplish, which means materially increasing the coal imported into France if pre-war consumption is to be reached, as the relief rendered from the Saar District will not compensate for the loss in productivity of the mines destroyed by the Germans. This situation is being promptly met in part by France in the appointment of a Commission to study the feasibility of the general electrification of all its railways with special reference to immediate construction in districts adjacent to its three large water-power groups, the Alps, the Pyrenees, and the Dordoyne or Central plateau region. It is proposed to electrify 5200 miles of its total of 26,000 miles of railways during a period covering twenty years. If this work is accomplished at a uniform rate of 260 miles a year, it is a most modest program considering the extreme necessity for the improvement.

In even worse plight is Italy with practically no coal of its own and compelled to import its total supply of 9,000,000 tons. The war has brought home to these countries what it means to be dependent upon imported fuel for their very existence and both Italy and Switzerland are also proceeding with extensive plans for railway electrification. Contrary to general understanding, the mines of Belgium are not destroyed, but the need of fuel economy is very acute and this country also has broad plans for railway electrification with immediate construction in view.

Recognizing the many advantages of electric operation of its railways, Europe furthermore considers this a most opportune time to start the change rather than to spend its limited funds in replacing worn out and obsolete steam equipment in kind. Also in marked contrast to the American attitude is the sympathetic interest and constructive assistance rendered by the Governments abroad in regard to the vital matter of rehabilitation of its railway systems. It would not be without precedent if the next decade witnessed England and the Continent outstripping this country in the exploitation of another industry which, while possibly not conceived here, has certainly been more fully developed and perfected in America than elsewhere.

From figures given, the conclusions in Table IX are arrived at in the matter of power station capacity required for complete electrification of the railways in the United States.

TABLE IX—RAILWAY POWER REQUIRED.

Kw-hr. electric operation, 1918	42,776,000,000 kw-hr.
Average load, 100 per cent load-factor	4,875,000 kw.
Power station capacity at 50 per cent load-factor	9,750,000 kw.

It appears therefore that approximately 10,000,000 kw. power station capacity would have been sufficient to run all the railroads for the year 1918, or one-half the station capacity which has been constructed during the past thirty years.

TABLE X—ESTIMATED POWER STATION CAPACITY, UNITED STATES, YEAR 1918.

Central stations	9,000,000 kw.
Electric railways	3,000,000 kw.
Isolated plants	8,000,000 kw.
Total	20,000,000 kw.

In the order of magnitude, therefore, it is not such a formidable problem to consider the matter of power supply for our electrified railways and it becomes evident also that the railway power demand will be secondary to industrial and miscellaneous requirements.

Such being the case, the question of frequency of electric power supply becomes of great importance, if full benefit is to be obtained from extensive interconnected generating and transmission systems covering the entire country. Indeed with the full development of interconnected power systems supplying both railway and industrial load from the same transmission wires, the above assumption of 50 per cent load-factor for the railway load can be materially bettered.

In this connection a method of limiting the troublesome peak load hitherto considered inherent to railway power supply has been in successful operation on the electrified C., M. & St. P. zone for the past year. With unrestrained peaks, the load-factor was approximately 40 per cent, but this low value has been raised to nearly 60 per cent by the installation of an inexpensive and most satisfactory device known as the power limiting and indicating apparatus.

TABLE XI—LOAD-FACTOR RECORDS, C., M. & ST. P. RY.

	Per Cent Duration of Peak	Per Cent Load-Factor
April	6.4	59.3
May	4.6	56.1
June	1.6	56.5
July	0.7	55.6
August	4.1	54.7
September	9.5	58.8

The readings in Table XI cover the performance on the 220 miles of the Rocky Mountain Division supplied by seven substations controlled as a unit. A load-factor of nearly 60 per

SMOKE CONDITIONS AS THEY EXISTED AT THE GRAND CENTRAL TERMINAL, NEW YORK, IN 1906

cent brings the electric railway within the list of desirable customers and makes it possible for power companies to quote attractively low rates for power.

Returning again to the question of power supply, it is instructive to note the general trend toward a higher frequency. It is quite evident that 60 cycles is rapidly becoming the standard frequency in America; and many instances are on record where it has replaced lower frequencies, principally 25 cycles. This fact in no manner handicaps the future development of electric railways, as entirely satisfactory power can be obtained from 60-cycle transmission lines through rotary converters, or synchronous motor-generator sets, depending upon the direct-current trolley voltage desired. Indeed a growing appreciation of the declining importance of 25-cycle power generation in this country contributed largely to the demise of the single-phase system, as its chief claim for recognition is wiped out with the introduction of the motor-generator substations required with 60-cycle supply.

While America apparently has adopted 60 cycles as its standard frequency and can look forward to unlimited interconnection of its large power systems, European practice is evidently crystallizing on 50 cycles. The situation abroad is as yet, however, not clearly defined. In such a small compact country as Switzerland for instance, where so much electrical development is taking place, there is much conflict of frequencies. Apparently there is little appreciation of the advantages resulting from interconnected power stations; in fact the Loetschberg Railway is supplied with power from 15-cycle waterwheel-driven generators placed in the same power station with 42-cycle units supplying industrial load while in the same immediate district there is a 50-cycle transmission line and no tie-in frequency changer sets as yet installed to interconnect any two frequencies. The power company, power consumer, and electrical manufacturer pay heavily for the complication imposed by maintaining three frequencies where only one is needed, and growing appreciation of this fact may lead to the standardization of 50 cycles in Switzerland and thus swing that country in line with its neighbors and ultimately bring about a more economical ratio of installed generator capacity to average load demand for the country as a whole.

A good example of the necessity for improvement in power distribution conditions in Switzerland is provided in the supply of power to the Loetschberg Railway as illustrated in Table XII.

TABLE XII—POWER SUPPLY TO THE LOETSCHBERG RAILWAY, MARCH, 1919.

Total for month	540,180 kw-hr.
Average of six 15 min. peaks	3,489 kw.
Load-factor, basis 24 hours	20.8 per cent

As the railway was operating for only seventeen hours per day, the load-factor during actual operation is somewhat better than 20.8 per cent. On the other hand, the actual momentary peak load greatly exceeded 3489 kw.; and this very fluctuating railway load furnishes a good illustration of the need of combining it with other diversified loads, in order to keep down the fixed investment of power station equipment now set aside for this isolated railway load. For example, the 60 per cent load-factor of the C., M. & St. P. power demand is the ratio of average to momentary peak while the Loetschberg Railway peak load is determined by six 15-min. peaks with momentary peaks greatly in excess of this figure.

Apparently the adoption of a standard frequency of 50 cycles would meet all general requirements in Switzerland, but would necessitate the installation of frequency changing substations to meet the demands for 15-cycle, single phase railway power. If the electrified railways are to benefit, therefore, from the establishment of a common generating and transmission system in Switzerland, the choice of the single-phase railway system might possibly be considered unfortunate, viewed in the light of modern development in power economics and the successful adaptation of the less expensive and more flexible direct-current motor to high trolley voltages.

From the power station standpoint, the electrification of our railways admits but one conclusion. We have some 63,000 engines now in operation and their average combined load amounts to approximately four million horse-power at the driver rims or only an insignificant total of 65 h.p. for each engine owned. It is true that, owing to shopping and for one cause or another, a large proportion of these engines are not in active service at all times, still the average twenty-four-hour output of each engine is less than ten per cent, of its rating. In the case of the C., M. & St. P. electrification, the average load of each individual electric locomotive is only 15 per cent of its continuous rating, but by supplying power to 45 electric locomotives from one transmission system, the average combined load-factor is raised to nearly 60 per cent, a figure which could even be surpassed on roads of more regular profile. Furthermore, when the railway load is merged with the lighting and industrial power of the district and the whole diversified load supplied from the same 60-cycle transmission and generating system, it is quite evident that all the conditions are most favorable for the efficient production of power. In this country such an achievement will probably be governed by the laws of economic return upon the capital required because our vast natural fuel resources are popularly regarded as inexhaustible, but in Europe there is the compelling spur of stern necessity behind the movement to utilize economically the water powers they possess in place of the coal they cannot get.

While the much discussed subject of power generation and transmission is a very vital part of the railway electrification

GRAND CENTRAL TERMINAL FROM 50TH STREET, SHOWING RESULTS OF ELECTRIFICATION

project, chief interest centers in the electric locomotive itself. Few realize what a truly wonderful development has taken place in this connection in a comparatively few years and how peculiarly fitted this type of motive power is to meet the requirements of rail transportation. Free from the limitations of the steam boiler, and possessing in the electric motor the most efficient and flexible known means of transmitting power to the driving axles, the electric locomotive gives promise of revolutionizing present steam railway practice when its capabilities become fully recognized. The only limits placed upon the speed and hauling capacity of a single locomotive are those imposed by track alinement and standard draft rigging. Only questions of cost and expediency control the size of the locomotive that can be built and operated by one man, as there are no mechanical or electrical limitations that have not been brushed aside by careful development. Just what this means in advancing the art of railroading is as yet but faintly grasped, any more than the boldest prophet of twenty years ago could have fully pictured the change that has taken place at the Grand Central Terminal as the result of replacing steam by eelctricity.

Progress in utilizing the capabilities of the electric locomotive has been slow. It is hard to break away from life-long railway traditions established by costly experience in many cases. In consequence the electric locomotive has thus far simply replaced the steam engine in nearly similar operation. Even under such conditions of only partial fulfillment of its possibilities, the electric locomotive has scored such a signal operating success as to justify giving it the fullest consideration in future railway improvement plans.

On the C., M. & St. P. Ry. 42 electric locomotives have replaced 112 steam engines and are hauling a greater tonnage with reserve capacity for still more. On this and other roads, electrification has set a new standard for reliability and low cost of operation. In fact, although no official figures have yet been published, it is an open secret that the reduction in previous steam operating expenses on the C., M. & St. P. Ry. are sufficient to show an attractive return upon the twelve and a half millions expended for the 440 miles of electrification, without deducting the value of the 112 steam engines released for service elsewhere. As the electric locomotive is destined to leave its deep impression upon the development history of our railways, it is fitting that the remainder of this paper should be devoted to its consideration.

Our steam engine construction is unsymmetrical in wheel arrangement, must run single ended, and is further handicapped with the addition of a tender to carry its fuel and water supply. The result has been much congestion at terminals; and the necessary roundhouses, always with the inevitable turn tables, ash pits, and coal and water facilities, have occupied much valuable land; and in addition steam operation has greatly depreciated the value of neighboring real estate. The contrast offered by the two large electric terminals in New York City is too apparent to need more than passing comment, and similar results may be expected on the fulfillment of plans for electrifying the Chicago terminals.

While it has been a simple matter to design electric locomotives to run double ended at the moderate speeds required in freight service, the problem of higher speed attainment, exceeding 60 miles per hour, has presented greater difficulties. The electric motor is however so adaptable to the needs of running gear design that electric locomotives are now in operation which can meet all the requirements of high-speed passenger train running. These results, also, are obtained with less than 40,000 lb. total weight, and 9,500 lb. non-spring borne or "dead" weight on each driving axle, and finally, but not least, with both front and rear trucks riding equally well, a success never before achieved in locomotives of such large capacity.

In connection with the riding qualities of electric locomotives, it is of interest to note the conclusions that the Committee of the American Railway Engineering Association, F. E. Turneaure, Chairman, reached in their report of 1917:

"From the results of the tests on the electrified section of the Chicago, Milwaukee & St. Paul Railway, the tests made in 1916 on the Norfolk and Western, and the few tests made in 1909 at Schenectady, N. Y., it would appear to be fairly well established that the impact effect from electric locomotives is very much less than from steam locomotives of the usual type. Comparing results obtained in these tests with the results from steam locomotives, it would appear that the impact from electric locomotives on structures exceeding, say, 25 ft. span length, is not more than one-third of the impact producted by steam locomotives."

There is as yet no general acceptance of a standard design of electric locomotive. Geared side-rod construction for heavy freight service and twin motors geared to a quill for passenger locomotives appear to find favor with the Westinghouse-Baldwin engineers, while the General Electric Company goes in for the simple arrangement of geared axle motors for freight and gearless motors for passenger locomotives. In both Switzerland and Italy the side-rod locomotive enjoys an almost exclusive field. How much of this preference for side-rod construction is due to the restrictions imposed by the use of alternating-current motors is hard to determine, but the facts available indicate both in this country and abroad the uniformly higher cost of repairs of this more complicated form of mechanical drive.

The electric railway situation in Italy is further complicated by the employment of three-phase induction motors with all the attendant handicaps of double overhead trolleys, low power-factor, constant speeds, and overheating of motors resulting from operation on ruling gradients with motors in cascade connection. In many respects the non-flexible three-

phase induction motor is poorly adapted to meet the varied requirements of universal electrification; and in consequence Italian engineers are still struggling with the vexing question of a system, which may, however, be in fair way of settlement through the adoption of a standard of 50 cycles as the frequency of a nation-wide interconnected power supply, thus throwing the preponderance of advantages to high-voltage direct current.

The extreme simplicity of the gearless motor locomotive appeals to many as does its enviable record of low maintenance cost, reliability, and high operating efficiency, as exemplified by its unvarying performance in the electrified zone of the New York Central for the past twelve years. Table XIII shows that the high cost of living did not appear to have reached this favored type of locomotive until the year 1918.

The records on the C., M. & St. P. locomotive are equally remarkable when considering their greater weight and more severe character of the service.

TABLE XIII—MAINTENANCE COSTS, NEW YORK CENTRAL.

	1913	1914	1915	1916	1917	1918
Number locomotives owned	48	62	63	63	73	73
Average weight, tons	118	118	118	118	118	118
Cost repairs per locomotive mile	4.32	4.03	4.45	3.78	4.01	6.26

TABLE XIV—LOCOMOTIVE MAINTENANCE COSTS, CHICAGO, MILWAUKEE & ST. PAUL RAILWAY.

	1916	1917	1918
Number locomotives owned	20	44	45
Average weight, tons	290	290	290
Cost repairs per loco. mile	8.21	9.62	10.87

In both these instances the cost of repairs approaches closely to three cents per 100 tons of locomotive weight. Giving due credit to the excellent repair shop service rendered in each case, it is instructive to note that three cents per 100 tons maintenance cost of these direct-current locomotives is less than half the figures given for any of the alternating-current locomotives operating in the United States or in Europe.

Compared with the cost of repairs for equivalent steam engines, the above figures for electric locomotives are so very favorable as to justify the general statement that electric motive power can be maintained for approximately one-third the cost of that of steam engines for the same train tonnage handled. As locomotive maintenance is a measure of reliability in service and in a way expresses the number of engine failures, it is quite in keeping with the records available to state also that the electric locomotive has introduced a new standard of reliability that effects material savings in engine and train crew expense as well.

While the first cost of electrification is admittedly high, it may in certain instances be the cheapest way to increase the tonnage carrying capacity of a single track especially in mountain districts where construction is most expensive and steam engine operation is most severely handicapped. In this connection a comparison of steam and electric operation on the C., M. & St. P. Ry. may be summarized as follows:

For the same freight tonnage handled over the Rocky Mountain Division, electric operation has effected a reduction of 22½ per cent in the number of trains, 24.5 per cent in the average time per train, and has improved the operating conditions so that nearly 30 per cent more tonnage can be handled by electric operation in about 80 per cent of the time it formerly took to handle the lesser tonnage by steam engines. This means a material increase in capacity of this single-track line which may be conservatively estimated in the order of at least 50 per cent and probably more. In other words, on this particular road, electrification has effected economies which sufficiently justify the capital expenditure incurred and furthermore has postponed for an indefinite period any necessity of constructing a second track through this difficult mountainous country.

A careful study of the seriously congested tracks of the Baltimore and Ohio Railroad between Grafton and Cumberland disclosed vitally interesting facts. Company coal movement in coal cars and engine tenders constituted over 11 per cent of the total ton-miles passing over the tracks. In other words, owing to the very broken profile of this division, the equivalent of one train in every nine is required to haul the coal burned on the engines. Taking advantage of this fact and the higher speed and hauling capacity of the electric locomotive and its freedom from delays due to taking on water and fuel, it is estimated that the three tracks now badly congested with present steam engine tonnage could carry 80 per cent more freight with electric locomotive operation. The coal output of the Fairmont District is largely restricted by the congestion of this division of the B. & O. R. R. and it is probable that equal relief with continued steam engine

A 5,000-TON FREIGHT TRAIN (100 CARS) ON THE CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY

operation could not be secured without the expenditure of a much larger sum for additional track facilities than would be needed to put electric locomotives upon the present tracks.

Further instances could be cited where the benfits of electrification are badly needed and many of these are coal carrying roads among which the Virginian Railway stands out conspicuously as a good opportunity to make both a necessary improvement and a sound investment.

Reviewing the progress made in a short twenty-year period, we have seen the steam turbine and electric generator drive the reciprocating engine from the stationary power field. The same replacement is now taking place on our ships, big and small, notwithstanding the fact that the marine reciprocating engine is a very good engine indeed and operates under the ideal conditions of steady load and constant speed. And now the steam locomotive must in turn give way to the electric motor for the same good reason that the reciprocating steam locomotive has become obsolete and fails to respond to our advancing needs. Electrification affords a cheaper and better means of securing increased track capacity and improved service than by laying more rails and continuing the operation of still more steam engines in the same old wasteful way.

To conclude the startling picture of our present railway inefficiency, we are today wasting enough fuel on our steam engines to pay interest charges on the cost of completely electrifying all the railways in the United States, fuel that Europe stands in sad need of and which England and Germany, the pre-war coal exporting countries, cannot now supply. With operating expenses mounting to 82 per cent of revenue, inadequate equipment and congestion of tracks, what we need in addition to constructive legislation and real cooperation on the part of the Government in the matter of rates and safeguarding invested capital, is wise direction in the expenditure of the large sums that must speedily be found and used to bring our railways abreast of the times. Accord full honor to the reciprocating steam engine for the great part it has played in the development of our railways and industries, but complete the work by replacing it with the electric motor and enter upon a new era of real railroading, not restricted steam engine railroading.

Measuring Thermal Expansions*

Accuracy of the Stretched Wire Dilatometer

By Arthur W. Gray

DETERMINATIONS of linear thermal expansivity involve:

(1) Production of temperature uniformity.
(2) Determination of temperature.
(3) Measurement of small length changes.

Of these, the last is by far the most difficult.

DIFFICULTIES IN MAKING RELIABLE MEASUREMENTS.

The difficulties that arise in connection with the measurement of length changes are of two kinds:

First, the displacements are generally so small that in order to attain even moderate percentage accuracy, high absolute accuracy is necessary. It is comparatively easy to arrange devices of sensitivity sufficient to indicate displacements smaller than one-tenth of a micron; but it is not quite so easy to attain such precision upon repeated attempts to measure the same length. It is not at all easy to make sure that such precision, when attained, represents real accuracy, that is to say, correctness.

In the second place, measurements of thermal expansions are far more difficult than ordinary length measurements requiring the same degree of accuracy. The very nature of the case demands that the body under investigation be measured at several different temperatures; and changes of temperature are always accompanied by displacements in various parts of the measuring apparatus. Unless special precautions are taken, these displacements give rise to errors which are always difficult, and often quite impossible, to determine with certainty. So-called compensating devices are generally unreliable. Rather than trust them when accuracy is of importance, it is better to design apparatus which will render the errors negligible, or at least will make them determinable with certainty.

It was for the reasons just given that the writer introduced the use of stretched wires in 1911 when designing for the Bureau of Standards the equipment still used in determining the thermal expansivity of materials in the form of bars.

STRETCHED WIRE METHOD FOR MEASURING LINEAR DISPLACEMENTS.

With the aid of such a simple device as a tightly stretched fine wire it is fairly easy to measure with great accuracy a displacement which occurs within a region otherwise difficult of access.[1]

Apparatus on this principle has been employed for the past eight years in the determination of thermal expansions. Two such arrangements of stretched wires are represented diagrammatically by Figs. 1 and 2. In each the expanding bar is indicated by *AB*. In Fig. 1, wires are freely suspended in contact with the ends of the bar and are stretched vertically by the weight of vanes immersed in oil, the viscosity of which is adjusted to damp any swinging of the wires so that their motions will be almost, but not quite, aperiodic. In Fig. 2, suitable for cases in which the bar is immersed in a liquid, wires are stretched upward to another bar *CD* rigidly connected with the central portion of *AB*. In both arrangements the transverse motions of the wires are observed through micrometer microscopes focused at convenient points *E* and *F*. Disturbances from changes in level are avoided by grinding ends of *AB* to form portions of a horizontal cylinder, the axis of which passes through the center of the bar.

ACCURACY AND RANGE OF THE METHOD.

Unless one has had actual experience with this method of rendering displacements accessible to measurement, it is difficult to believe the accuracy attainable when proper precautions are taken. Thousands of observations have convinced me that the method is the most reliable yet devised for the measurement of thermal expansions. I have used the arrangement of Fig. 2 in an oil bath maintained at any desired temperature from near —150 deg. C. up to +350 deg. C., and I have used the arrangement of Fig. 1 in an electric furnace at various temperatures up to about 650 deg. C. I have not personally tested the method at temperatures much above 650 deg. C. Sufficiently fine wires of nichrome or other non-oxidizable material strong enough at higher temperatures to sustain the weights of the damping vanes were not obtainable while I was at the Bureau of Standards. Nor were my ar-

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[1]Expansion measurements by this method were reported to the American Physical Society at the Washington meeting in December, 1911, and at various times since then. (A. W. Gray: "A New Type of Apparatus for Measuring Linear Expansion," *Phys. Rev.*, Vol. 34, p. 139, 1912.) The principle of the method was also described in a communication to the Washington Academy of Sciences. ("New Methods for Displacement Measurements and Temperature Uniformity Applied to the Determination of Linear Expansivity," *Journ.*, Wash. Acad. Sc., Vol. 2, p. 248, 1912.) See also "Production of Temperature Uniformity in an Electric Furnace," Bull. Bureau of Standards, Vol. 10, p. 451, 1914; Scientific Paper No. 219.

rangements completed for an atmosphere within the furnace which would permit the use of tungsten wires. Recently, however, Dr. Souder, who is now in charge of the Expansion Laboratory, informed me that the Bureau had obtained fine enough wires of a nickel-chromium alloy which, even in air, remained sufficiently strong at temperatures up to 1000 deg. C. Tungsten, if protected from oxidation, could probably be used up to 1400 deg. C., or perhaps even higher.[2]

The stretched wire method of measuring expansions has not yet been tried at temperatures below —150 deg. C., because suitable temperature baths have not been conveniently available. The pentane which was used for the bath liquid becomes so viscous when cooled to near —150 deg. C. that proper circulation is no longer possible. It would, however, be a simple matter to modify the apparatus so as to use a bath of liquid air; and, with such refrigerating facilities as are available in the Cryogenic Laboratory of Kamerlingh Onnes, the wire method could be used down to the very lowest temperatures producible with the aid of liquefied helium. It is merely a question of sufficient refrigeration and a suitable container for the bath.

The complete equipment which I planned for the Bureau of

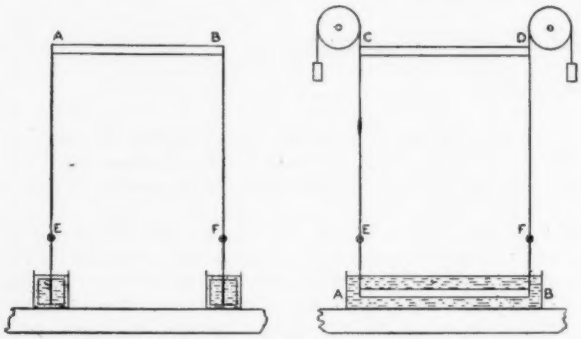

FIG. 1 & 2. DIAGRAM OF STRETCHED WIRE DILATOMETER

Standards has never been finished, and consequently has not been described; but some accounts of measurements made with this apparatus at various temperatures ranging from below —140 deg. C. to above 600 deg. C. have recently been published by my former assistants Schad and Hidnert, by Merica and Schad, and by Price and Davidson.[3]

The data contained in these papers, some of which are presented graphically, illustrate the performance of stretched wire expansion apparatus under conditions of ordinary routine tests. The precision is most clearly shown by Schad's and Hidnert's measurements of the expansivity of molybdenum. They found that all their length observations made at temperatures ranging from —142.5 deg. to +18.7 deg. C. were expressible by a quadratic equation with such precision that the probable error of a single observation was ±2.6 microns per meter. Likewise, the probable error of a single observation on heating from 18.7 to 305.3 deg. C. was found to be ±2.5 microns per meter. Since the specimen tested was only 20 cm. long, these values indicate that the probable error in making a single expansion measurement was about ±0.5 micron. Moreover, a second set of observations from room temperature to 304 deg. C., taken several days later, yielded an equation which agreed so closely with that obtained during the first test that the lengths determined from the two equations did not differ by more than 4 microns per meter, or 0.8 micron in length actually measured. Some of the slight differences observable between heating and cooling curves, and between curves obtained from different tests of the same specimen, are due to the fact that no solid has yet been found which assumes exactly the same dimensions every time it is

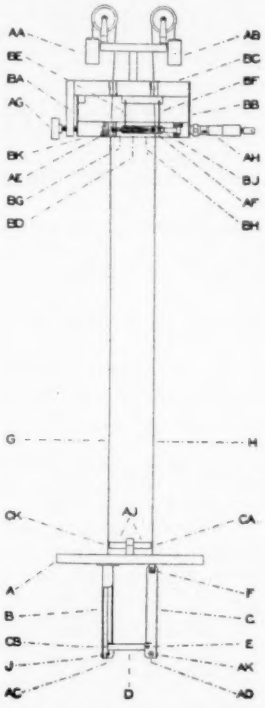

FIG. 3. SKETCH OF ESSENTIAL PARTS OF DILATOMETER

brought to the same temperature. Molybdenum repeats better than most substances, and is, therefore, well suited for expansion apparatus.

SIMPLE STRETCHED WIRE DILATOMETER.

While the equipment developed at the Bureau of Standards is very efficient for the accurate investigation of thermal expansivity over a wide temperature range, it is more elaborate than is necessary for most scientific or industrial purposes. A simple but reliable dilatometer which the writer made from material to be found in almost any physical laboratory may therefore be of sufficient interest to warrant a more detailed description that that already published.[4] The apparatus, which uses the stretched wire method of measuring linear displacements, could easily be adapted for commercial testing. It differs from the precision apparatus at the Bureau of Standards mainly in the substitution of an ordinary Brown & Sharpe micrometer screw for the expensive microscope comparator and reference bar. Fig. 3 is a somewhat diagrammatic vertical projection of the dilatometer partly in section.

[2]Jeffries recently found the equi-cohesive temperature of platinum to lie between 525 and 550 deg. C. This explains why I could not get platinum wire to sustain continuously the weights of even very light damping vanes when the temperature rose much above 600 deg. C. Jeffries found the equi-cohesive temperature of tungsten to be about 1350 deg. C. (Zay Jeffries: "The Amorphous Metal Hypothesis and Equi-Cohesive Temperatures," *Journ.*, Am. Inst. Metals, Vol. 11, pp. 300-323, 1917.)

[3]L. W. Schad and Peter Hidnert: "Preliminary Determination of the Thermal Expansion of Molybdenum." Bull. Bur. Standards, Vol. 15, pp. 31-40, 1919. P. D. Merica and L. W. Schad: "Thermal Expansion of Alpha and of Beta Brass between 0 and 600 deg. C., in Relation to the Mechanical Properties of Heterogeneous Brasses of the Muntz Metal Type," *Journ.*, Am. Inst. Metals, Vol. 11, pp. 396-407, 1917; Bull. Bur. Standards, Vol. 14, pp. 571-590, 1918. W. B. Price and Philip Davidson: "Physical Tests on Common High Brass Taken Parallel and at Right Angles to the Direction of Rolling-Appendix," *Trans. Am. Inst. Metals*, Vol. 10, 1916.

The expansion determinations reported by Price and Davidson were planned in detail by the present writer; the measurements and charts were made by Messrs. Schad and Hidnert; the specimens of brass were furnished by Mr. Price.

[4]Abstract of a paper presented at the Baltimore meeting of the American Physical Society. *Phys. Rev.*, Vol. 13, p. 142, 1919.

Minor constructional details are not represented in order that the essentials may stand out more clearly.

DETAILED DESCRIPTION OF SIMPLIFIED APPARATUS.

Extending vertically downward from the cover *A* of the temperature bath made of asbestos wood are two tubes *B* and *C*, the axes of which are separated by approximately the length of the specimen *D*. At the lower end of each tube are two pointed co-axial screws *E* for clamping *D* from opposite sides. One of the tubes, *B*, is rigidly attached to the cover *A*; the other, *C*, is hinged at *F* so as to permit free expansion of the specimen. Fine wires, *G* and *H*, of annealed tungsten, clamped to the lower ends of the tubes by means of the screws *J* and *AK*, extend vertically upward through the tubes and the cover for several decimeters above the latter, where they pass over pulleys and support weights *AA* and *AB*, which keep them tight and straight. The pins *AC* and *AD* cause the wires to bear firmly against the rounded ends of the specimen *D*. Small circumferential V-grooves in these pins center the wires and prevent them from slipping across the ends of the specimen.

At the upper end of the apparatus are two smooth round pins *AE* and *AF*, which bear against the wires *G* and *H*, a decimeter or so below the pulleys. By means of the screws *AG* and *AH* these pins move horizontally in the plane of the wires, so that the upper portions of these wires can be brought closer together or separated a measured distance.

Just above the cover of the temperature bath is placed a horizontal bar *AJ*, of low and known thermal expansivity, protected as far as possible from temperature changes accompanying warming and cooling of the bath below.

This bath, which is not shown in the illustrations, is of oil, heated electrically, and continuously stirred by a screw propeller, the containing tank being provided with suitable guides for insuring thorough mixing and circulation. If air is excluded to prevent flashing, "Renown" engine oil can be used to over 300 deg. C. Pentane gasoline remains sufficiently fluid down to about —150 deg. C. Although these two liquids will cover the entire range, kerosene is usually the most convenient substance when measurements do not have to be extended much beyond either 0 deg. or 75 deg.

After the specimen has been placed in the heating bath and temperature equilibrium has been reached, the upper end of each stretched wire is moved until the wire just touches the end of the bar *AJ*. Contact is indicated electrically by means of an inexpensive reflecting galvanometer in series with a dry cell and a suitable resistance. As the specimen *D* expands, it moves the wires away from the contact bar *AJ*. The magnitude of the expansion is determined from the movements of the screws *AG* and *AH* required to restore contact.

Only one graduated screw is actually used. The ordinary screw *AG*, of moderately fine pitch, moves a horizontal bar *BK*, to which are rigidly attached both the pin *AE*, which communicates the motion to the left-hand wire *G*, and the nut of the graduated screw *AH*, which moves the right-hand wire *H*. In this way a single micrometer screw is made to measure the total displacement of both wires. A Brown & Sharpe micrometer head is convenient for this purpose.

The movement of the bar *BK* is guided without lost motion by means of the thin flat strips of spring metal *BA* and *BB*, which suspend it from the bar *BC*. The smaller bar *BD*, which carries the pin *AF*, is likewise supported by the flexible strips *BE* and *BF* so that it is freely movable horizontally within a rectangular cavity cut through the central portion of *BK*. The spiral spring *BG* surrounding the rod *BH* presses *BD* firmly against the end of the measuring screw *AH*. The steel ball *BJ*, pressed tightly into the end of *BD*, makes an excellent bearing for the end of the screw.

The bar *AJ* is merely a piece of Pyrex glass tubing. (Fused quartz, because of its still smaller thermal expansivity, would be better.) Bearing firmly against each end of the tube, a tungsten wire (*CK* and *CA*) about 0.1 mm. in diameter is tightly stretched horizontally between two posts, one of which serves to connect the wire electrically with the galvanometer for detecting contact with the adjacent vertically stretched measuring wire. These posts, which may be ordinary machine screws with nuts, are not represented in Fig. 3. The ends of the tube are, of course, suitably ground so that the horizontal wires will be parallel to each other, and so that there will be no interference with the motions of the vertical wires. The horizontal wires define the effective length of the contact bar *AJ*.

PREPARATION OF SPECIMENS FOR TESTING.

The preparation of a specimen for an expansivity determination is an easy matter. All that is necessary is to cut off a rod of the required length and to round the ends smoothly, so that they form portions of a cylindrical surface. The rounding should, however, be accurately done, since its purpose is to prevent small angular displacements in the plane of the wires, causing errors by changing the distance between contacts. The easiest and best way of producing the cylindrical surfaces is by grinding.

A simple tool is used for holding a specimen during this operation. By means of radial screws near each end the rod is firmly clamped within a metal tube. Midway between its ends this tube is pivoted between two co-axial pointed screws which hold it within the arms of a forked bar of rectangular cross-section. As the bar is gradually advanced toward the edge of the grinding wheel, the tube containing the specimen is rotated between the pivot screws of the fork.

A screw-operated slide-rest is not at all necessary for feeding the specimen toward the grinding wheel. With the exercise of a little care the movement can be sufficiently well guided by pressing one corner of the forked bar into the dihedral angle of a support formed by fastening a straight strip of wood or metal upon a flat surface. The bar is advanced toward the wheel by gentle tapping against the farther end. Even glass can be ground in this way without difficulty.

Near each end of the tube which holds the specimen during grinding are two small holes, one from each side. These form convenient guides for drilling the little conical depressions or holes (*CB*, Fig. 3) that receive the pointed ends of the clamping screws *E*.

SOURCES OF ERROR.

The accuracy of the simple dilatometer described above is limited mainly by the accuracy with which contact can be detected between the stretched wires and the bar *AJ* above the temperature bath. Immediately before taking a series of readings the contact surfaces of both the wires and the bar should be washed with a little ether applied by means of a camel's hair brush. With delicate touch the left-hand screw *AG* is then cautiously and steadily turned until the galvanometer gives the first slight indication of contact between the wire *G* and the end of the contact bar *AJ*. A small deflection that increases with continued advance of the screw indicates a better contact than a sudden, large deflection. After contact has been established with the left-hand wire, the measuring screw *AH* is advanced until the right-hand wire *H* makes contact with *AJ*. At each temperature or measurement, settings of both screws should be repeated a sufficient number of times to make sure that good contacts are being obtained. Failure to obtain a series of concordant readings is evidence that something is wrong—probably a dirty contact or lack of care in turning one of the screws.

The effect of errors in the measuring screw varies inversely as the ratio of the distances from the contact bar *AJ* to the pins *AE* and *AF* for moving the wires and to the specimen *D*. In the apparatus actually used these pins were 600 mm. above and the specimen 150 mm. below the bar, so that the micrometer screw *AH* measured four times the expansion of the specimen. The results showed that with proper use deviations of individual screw readings from the average should not

exceed 5 microns. The average deviation of 107 individual readings from the average reading for each temperature was less than 2 microns, corresponding to an average deviation of 0.5 micron in determining the expansion of the speciment.

Corrections must be applied on account of length changes in *AJ* and in *BK* brought about by temperature changes occurring in these bars during the course of an expansivity determination. With a dilatometer in which the wires multiply the elongations by 4, the apparent expansion of the specimen must be corrected as the expansion of *AJ* and ¼ the expansion of *BK*. Although it is easy to calculate these corrections if the expansivities and the temperatures of *AJ* and *BK* are known, it is more convenient to render the corrections negligible, or at last very small, both by using materials of low expansivity for these parts of the apparatus and by protecting them from temperature changes—especially changes caused by convection, conduction and radiation from the bath for heating the specimen under test.

CONCRETE ILLUSTRATION OF AN EXPANSIVE DETERMINATION.

A concrete example illustrating the capabilities of the above-described simple apparatus is afforded by a determination of the thermal expansivity of some optical glass.[5]

A summary of the measurements made is contained in the accompanying table. In this table Column A gives in degrees Centigrade the temperatures of the oil bath in which the specimen was heated. These temperatures were determined by platinum resistance thermometer; a mercurial thermometer was used as a rough indicator. Column B gives in microns the expansion of the specimen observed on heating it from 23.45 deg. to each temperature recorded in Column A. In obtaining these values the corrections given in Column D were added to the apparent expansions indicated by the measuring screw. For calculating the corrections the linear expansivities of the brass bar *BK* and of the Pyrex glass tube *AJ* were assumed to be 0.000018 and 0.0000032 per degree Centigrade, respectively. The magnitudes of these corrections could have been greatly reduced by proper choice of materials together with proper thermal insulation.

THERMAL EXPANSION OF OPTICAL GLASS

A	B	C	D	E
23.45	0.0	±0.5	—2.8	7
77.51	25.5	0.6	—2.5	3
78.21	29.2	0.4	—1.0	8
127.24	47.2	0.4	+0.2	9
170.55	67.2	0.2	+2.0	6
227.83	95.8	0.3	+3.0	10
254.13	110.0	0.6	+3.2	9
265.75	115.5	0.5	+3.0	7
276.62	120.8	0.5	+3.0	9
286.39	124.2	0.4	+4.0	9
297.07	130.0	0.6	+4.5	6
307.81	133.5	0.4	+5.8	7
30.85	13.8	0.6	—2.0	7
29.96	13.0	0.5	—1.2	10

A. Temperature Centigrade.
B. Expansion in microns of 6 cm. specimen.
C. Average deviation in microns from average.
D. Correction in microns for temperature changes in apparatus.
E. Number of micrometer screw settings averaged.

The precision attained in measuring the expansions is indicated by Column C, which gives opposite each temperature the average deviation in microns of the individual indications of the measuring screw from the average value observed at that temperature. The deviations here recorded, which correspond to elongation of the specimen under measurement, were obtained by dividing the corresponding deviations of the actual screw readings by 4, since the stretched wires multiplied the specimen elongations by 4. Column E shows the number of micrometer screw observations that were averaged at each temperature to obtain the values under B and C. Examination of the table shows that, for the 107 contact observations represented, the average deviation was only about 0.46 micron. This gives some idea of the high precision attainable with a stretched wire dilatometer even when the construction of the instrument is crude.

A plot representing the observations recorded in the table is shown in Fig. 4. The straight line corresponds to an expansivity of 0.00000794 per degree Centigrade. The last two observations, which were made the day following the observation near 308 deg., are represented by the open circles. Such failure of a glass to return to its original length upon cooling after strong heating is frequently observed.

Although Fig. 4 indicates an accuracy sufficient for most scientific or industrial purposes, it should be borne in mind that the specimen tested was only 60 mm. long and that the corrections given in Column D of the table are both considerably larger and considerably more uncertain than need be. If the errors involved in the corrections be rendered negligible by the means indicated above, the relative accuracy of the expansion measurements will be increased in the same ratio as the length of the specimen under test is increased, since the deviations in Column C represent absolute, not relative, precision in length measurement.

VARIATIONS OF THE STRETCHED WIRE DILATOMETER.

The apparatus actually constructed as outlined above illustrates merely one particular arrangement for applying the general principles of the stretched wire method. It was hastily designed and built to meet an emergency. Various details could obviously be modified. For example, two independent graduated screws for moving the stretched wires *G* and *H* would be a convenience; any sensitive detector of contact is usable; tungsten wires are not necessary, etc. Moreover, micrometer screws can be arranged to replace microscopes for use with either an air bath (as in an electric furnace) or a liquid bath; so that the range of application even in the simplified form of dilatometer is not limited to the interval between room temperature and 300 deg. C.

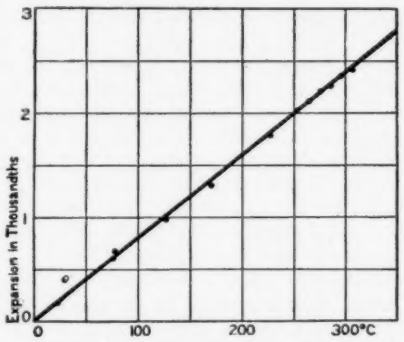

FIG. 4. THERMAL EXPANSION OF OPTICAL GLASS

Nor is the application of the stretched wire method limited to the case of thermal expansion. The writer has already used wires for measuring magnetostriction in nickel steels at temperatures ranging from —75 deg. to +300 deg. C. Wires could easily be adapted to the construction of an extensometer for measuring deformations of materials during any kind of testing, especially when it was desired to control the temperature of the test piece. In fact, there appears to be no other method that is quite so reliable for accurately following linear displacements that occur in regions which are difficult of access.

[5]At the request of Dr. Arthur L. Day, Optical Glass Committee, War Industries Board, the writer undertook to determine the expansivity of this glass, which had been produced under the direction of the former for naval searchlight mirrors. The dilatometer shown in Fig. 3 was hastily designed and constructed especially for this work.

CORRECTION.

WE regret to state that in the article on "Non-Rolling Passenger Liners," p. 232 of the March issue of the SCIENTIFIC AMERICAN MONTHLY, the author's name was given as "Edward A. Sperry." It should have been "Elmer A. Sperry." The story of Mr. Sperry's achievements as an inventor is told in the SCIENTIFIC AMERICAN of April 17, 1920.

Science and National Progress

Edited by a Committee of the National Research Council

Dr. Vernon Kellogg, Chairman, Dr. R. M. Yerkes, H. E. Howe

BLUE EYES AND BLUE FEATHERS.

By Wilder D. Bancroft.

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The National Research Council is a cooperative organization of the scientific men of America. It is established under the auspices of the National Academy of Sciences and its membership is largely composed of appointed representatives of the major scientific and technical societies of the country. Its purposes are the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the national strength and well-being.

THE color of red paint or of yellow paint is due to red or yellow pigments, which owe their color to their chemical nature. These are called pigment colors. There are other colors which are due to the physical structure, and which are therefore called structural colors. The rainbow, for instance, is not a painted band in the sky. In fact, no two people see the same rainbow. Structural colors may be due to a number of causes and to understand them it is necessary to start almost at the beginning. An absolutely smooth, reflecting surface is invisible. We realize this very often when we come unexpectedly face to face with an exceptionally good mirror. It was suggested by a German that the Zeppelins should be coated with a polished metallic surface which would make them perfectly invisible. While it would be impossible to see such a surface, there is some doubt whether this would be a great success from a military point of view, because almost anybody would realize that something queer was going on if he were to see a reflected section of the earth's surface apparently moving along up in the sky.

If we put powdered glass in a liquid having the same index of refraction as the glass, no light is refracted when passing through the mixture and consequently the glass is invisible. If a glass rod be dipped into such a liquid, the rod seems to melt and disappear when it touches the surface of the liquid. Since different colors may have different indices of refraction, it happens sometimes that the glass will be invisible for certain rays, which are transmitted without change, while other rays are scattered by the glass. Under these circumstances the mixture of glass and liquid may transmit only yellow light and will appear yellow. At some other temperature it may transmit only red or only blue. This is known as the Christiansen effect, from the man who first studied it.

If we have a thin film with light reflected from the front and the back surfaces, it may happen that the crest of certain waves reflected from one surface will coincide with the hollow of waves reflected from the other surface, in which case this particular color will disappear and the place where this disappearance occurs will appear to have the complementary color. The colors of thin films are often known as Newton's Rings. We are quite familiar with them in the case of soap bubbles and with oil films on the ground. In the streets of Washington the colors due to oil films are exceptionally brilliant; but this is not due to any particular brand of oil which is spilled there. It is because the streets are asphalted and consequently there is practically no reflection of light from the asphalt surface to interfere with the colors of thin films. This is a very good illustration of the importance of a dark background in the case of structural colors.

We may get colors by reflection and refraction. The rainbow is an illustration of this. The old-fashioned cut-glass chandelier gives a good example of the colors that may be produced by light passing through a prism. If we have a number of lines ruled parallel and very close together on a smooth surface, this gives us what is known as a diffraction grating, which may spread a ray of light out in a way very similar to a prism. Agates are composed of thin films about 0.001 of a millimeter in thickness, and when the agate is properly cut it may behave like a diffraction grating. In the case of mother-of-pearl, we have alternate layers of calcium carbonate and an organic material. These layers overlap very slightly in a regular fashion and consequently act to some extent like a diffraction grating, giving rise to the peculiar effect known as pearly lustre.

The reflection of light by powdered material may produce a number of interesting color phenomena. When white light is scattered from a surface instead of being reflected as in a mirror, it gives rise to the sensation of white. A block of ice is not white, because it does not scatter the light. If the ice is powdered, or still better if we have snow, the light is scattered and we call the snow white. Instead of having solid particles of ice in air we may have air bubbles embedded in liquid, in which case we get a white froth or foam. If the blue crystals of copper sulphate are ground to a fine powder, the light passes through such fine layers of the material that it does not become colored blue to any appreciable extent. On the other hand, the light is scattered from the powdered surfaces, and the powdered copper sulphate looks white instead of blue. When silver is precipitated by an electric current, it does not come down with a mirror-like surface, but rather in a mass of tiny crystals which scatter the light in every direction. Consequently electrolytic silver is white and only has the characteristic appearance of silver after it has been burnished. There is no white pigment in any white flower or in white hair, and probably not in white bark. The white color of the lily is due to the presence of innumerable air bubbles and the same is true of white hair. In order that hair may turn white in a single night, it is not necessary for the original pigment to disappear and for white pigment to develop. It is only necessary for a mass of minute air bubbles to be formed in the hair as a result of worry. While this accounts for the physical change, we are as much at a loss as ever to know why intense grief should develop air bubbles in the hair.

The scattering of light by a powder or by the fibers of a sheet of paper is due to the difference in the index of defraction between the solid particles and the air. If we replace the air by some liquid having very nearly the same index of refraction as the solid particles, these latter will cease to be white and will become more transparent. It is well known that oiled paper is distinctly translucent. If powdered copper sulphate were immersed in a liquid having about the same index of refraction as the crystals, these would probably become blue. This experiment has not been tried; but there is a more interesting one which has puzzled people for a good while. In the zoölogical gardens some flamingoes are much redder than others. At one time it was thought that the redness was connected with a fish diet; but flamingoes have been raised which had bright red feathers even though the birds had never eaten fish, so this explanation had to be given up. It is now believed that the brilliancy of the color is due to the presence of oil in the feathers, this making them more translu-

cent and bringing out the red color. Water colors always become paler as the water dries out, because the pigment is then surrounded by air and not by water. Some people have gone so far as to say that white pigments do not occur in nature in living beings; but this is an over-statement. Some butterflies have a whitish pigment in their wings and the white bellies of many fishes are due to the presence of a substance called guanin, and not to air bubbles.

Complete absorption of light gives the sensation known as black. Pulverulent silver is black because the crystals are so arranged that all the light is absorbed by reflection forward and back. This can be shown in another way. If we take a bunch of steel needles and place them with their points side by side facing the observer, the mass will appear black, although we know that no single needle is black in itself. The rich color of velvet is due to its trapping the light, and the peculiar effect known as damask is due to the fibers being arranged in two different ways, so that one set absorbs more light than the other. Trees and grass may act as light traps when seen from above and they are said to look black to aviators. If we have a material which absorbs light so completely that the powder is black, we shall get all gradations between the original color and black if we grind up such a substance, just as we got all variations between blue and white by grinding crystals of copper sulphate. If we start with yellow gold and make it more porous, it will become brown before becoming black. This happens unintentionally in the assaying of gold, a brown powder being obtained which people have thought was an allotropic form of the metal. It is merely a porous gold and when it is heated until the crystals sinter together and become less porous, the yellow color of gold reappears.

When powders are grouped, there may also be a change of tint owing to the fact that the pigment or absorption color varies with the thickness of the film. This will show up just as well with thin layers as with powders. Both cobalt glass and cyanine are blue in thin layers and red in thick ones. Large crystals of potassium ferricyanide are red and the color changes to yellow when the crystals are ground to powder. It has been made probable by the Geophysical Laboratory that rouge would be yellow if we could grind it fine enough. So far this has not yet been done; but it is merely a question of time when somebody will make yellow rouge, in spite of the contradiction in terms which is implied. In all these cases adding a liquid having approximately the same index of refraction as the powders would change the color towards that of the larger crystals.

If we have very fine particles suspended in a transparent solid, liquid, or gas, these particles scatter blue light much more than they do red light, and consequently such a mass appears red by transmitted light and blue by reflected light. Skimmed milk is an instance of this sort, being distinctly bluish by reflected light and reddish by transmitted light. Tobacco smoke is also blue by reflected light and red by transmitted light. The blue color of the sky is due to light which is scattered by drops of liquid or by particles of dust in the air. The intensity of the color is undoubtedly increased by the fact that we see this against the black background of infinite space, so that the color is not changed by light reflected from the boundaries of the atmosphere.

There is no blue pigment in blue eyes and it was pointed out by Tyndall years ago that the blue of the eye is really the blue of turbid media, and is thus analogous to the blue of the sky or the blue of skimmed milk. At the back of the iris there is a dark pigment known as the *uvea*, which prevents the reflection of light and keeps the color of the blood behind it from being seen. When this dark pigment is absent, we have an albino and a pink eye. The various stages between the blue and the gray eye are due to differences in the coarseness of the particles giving rise to the blue color, the blue color being the more intense the finer the particles. This is probably the reason why babies' eyes are so very blue, because the suspended particles tend to grow coarser with increasing age. All other people have a yellowish-brown pigment in the front of the iris, and the combination of the structural blue with the yellowish-brown pigment gives rise to the green, hazel, brown and black eyes. Except with people who have very black eyes, the pigment in the front of the iris does not develop at birth, just as the teeth do not come till later. Consequently most babies have blue eyes, the color changing to hazel, brown or black as they grow older, while the reverse change never occurs. Once in a while we see a man whose eyes are colored differently. This means that pigment has developed in one eye and not in the other, or that the pigment has developed unequally in the two eyes. The green eye is due to the combination of structural blue with the pigment yellow. While this is not a common type in human beings, we get it very markedly in the case of the green tree-frog, which has no green pigment and whose green color is due to structural blue with a yellow pigment overlaying it. If we scrape the pigment layer off the back of an unfortunate frog, he turns blue. The Latin name of the Australian tree-frog means "the sky-blue frog," because he is blue when he comes to us preserved in alcohol, the alcohol having dissolved the yellow pigment.

If we leave out of account feathers with a blue metallic lustre, which may constitute a special case, we may say that there is no blue pigment in the feathers of any bird. This means that the blue of the kingfisher, the indigo bunting, the blue-jay, and the blue-bird, is not due to blue pigment, but is a structural color. The only pigment in the blue feathers of these birds is a dark brown one which apparently serves merely as a background, just as in the case of the blue eyes. The best explanation of the blue feather is that the horny matter is filled with an enormous number of minute air bubbles, which scatter blue light and transmit red, which is absorbed by the dark background. The blue feather is therefore the same in principle as, and the opposite in detail from, the blue sky. The color of the sky is due to the scattering of light by particles of liquid or solid suspended in a gas, the air. The blue of the feathers is due to the scattering of light by bubbles of gas, air, suspended in a solid medium. While this explanation is undoubtedly the right one, nothing analogous to a blue feather has yet been made in the laboratory. This is one of the things that people must do in the future.

In this country the tufted titmouse is a gray bird with no brilliant colors; but the German titmice show great differences in color. One variety is green on the back, due to structural blue overlaid by a pigment yellow, and yellow on the belly. In another variety the brown pigment which is essential to the structural blue has not developed and the bird is consequently yellow all over. There is a third form in which the yellow pigment has not developed and the bird is therefore blue on the back and white underneath. One would like to think that the differences in color between the male and the female redstart were of this type and were due to the presence in the male of a single color which is lacking in the female; but this seems not to be the case.

The gorgeous sunset colors are due to the red light which is transmitted through the cloudy sky and is the reverse of the blue of the sky. Water is apparently blue in itself when one looks through a sufficiently long layer. If, however, there were nothing to reflect the light back, the water would, of course, look black, and certain lakes do show exactly this phenomenon. If there is a small amount of reflecting particles, the water looks blue. With more suspended particles a certain amount of yellow is sent back, and the water becomes green. In the tropics the water is an intense blue, except near the shore, where it becomes an almost equally intense green. The water of the Rhone where it flows out of the Lake of Geneva is blue, while the Rhine at Strassburg is green, and we find that the Rhine contains seventy per cent more suspended calcium carbonate than the Rhone. Sometimes the water in a swimming tank will be as green as crême de menthe. This is due to suspended solids in the water. The same effect can oc-

casionally be obtained in a porcelain-lined bath tub. The clear brown brooks that one finds in many places in New England owe their color to the presence of a brown material of the nature of tannin, so this would really be a pigment color and not a structural one.

If a substance absorbs light very strongly, it may also reflect that light selectively, in which case the substance has what we call a surface color, due to resonance. Instances of this sort are very common among the so-called aniline dyes. For instance, crystals of magenta transmit red but reflect green Substances having marked surface colors show some very extraordinary properties when present in the form of very finely divided particles. Indigo in mass transmits blue and reflects red. If we make a colloidal solution of indigo with very fine particles, we find that it transmits red and scatters blue light. Without going into the theory of this, we may make the assumption that a substance which has a surface color will transmit, in finely divided form, the light which it ordinarily reflects, and will scatter the light which it ordinarily transmits. This tentative hypothesis works out very well as a means of explaining the colors of colloidal gold and colloidal silver. The apparent surface color of gold is yellow; but if we make the light pass a number of times between two surfaces of gold, we find that the resulting color is red and not yellow. A thin film of gold transmits green. In accordance with the hypothesis, we find that a colloidal solution of gold having very fine particles transmits red light and scatters green light. If the particles are coarse enough so that the peculiar phenomenon of resonance does not take place, the particles scatter yellow or brown light and transmit blue. As we see it ordinarily, silver has no especial color; but after multiple reflection, we find that the surface color or silver is yellow. A thin film of silver transmits blue and a colloidal solution of silver consequently transmits yellow light and scatters blue. With coarser particles, we get the transmission of blue, which is in line with the behavior of silver films, and the silver scatters the complementary color, which is blue. Sodium fogs scatter violet light, for which the vapors are transparent.

Michelson, of Chicago, has shown that the brilliant colors of butterflies are due in many cases to surface colors so that it is probable that the wings of the butterflies are colored by solid pigments, which behave like such aniline colors as magenta.

We are accustomed to say that metals have a metallic lustre and that glass has a vitreous lustre; but this does not seem to get us ahead at all. If one asks a physicist what constitutes metallic lustre, he is very likely to say that metals conduct electricity and that the electrons which are present give rise to the sensation of lustre. This cannot be the whole truth, because an empty glass test-tube placed in water and looked at so as to give total reflection, is more metallic than mercury itself. Also, if we take a black image on a white ground and a white image on a black ground and combine these two in a stereoscope, we do not get a sensation of gray—we get metallic lustre. A similar effect is obtained if we have a yellow image on a blue ground and combine it with a blue image on a yellow ground. This shows that the problem of metallic lustre is a psychological one in some cases and possibly in all. It seems probable that one gets the sensation of metallic lustre whenever we have a nervous flutter or unsteadiness of attention, as when one combines two pictures having different degrees of brightness. The elements of fatigue would enter in very largely here and some people are much more sensitive to binocular lustre, as it is called, than others. Woolen goods striped black and white appear lustrous to a few people, though not to most. This seems to be an exaggerated case of the eyes wandering over the surface in a jerky manner.

With metals there is reflection from the surface and from a plane only just below the surface, this giving rise to the flutter effect. When looking at a thing which is not in itself a metal, the sensation of metallic lustre will be attained more easily if the texture of the surface of the material resembles that of a metal. We also get the sensation of lustre in cases in which there is simultaneously a roughened surface and a high reflection of light. The most familiar instance of this is the silvery streak which marks the reflection of the moon from a water surface rippled by the evening breeze. The wavelets make the surface of the water seem rough and the accompanying high reflection of light makes the water look metallic, even more metallic than the disk of the moon itself.

Even in the best colored moving-picture films, we do not get the sensation of metallic lustre because both eyes are looking at the same image. It seems probable that this could be overcome in case the photographs were taken by means of two or more lenses sufficiently far apart. On the other hand, it would be very easy to overdo this, with the result either of getting a blurred image or of getting one with a metallic shine over everything, which would be worse than the present arrangement.

What is probably the color of colloidal particles is to be noticed with gems. Colorless topaz is made orange by radium and heating makes it colorless again. Ultra-violet light tends to change the orange, due to the radium, to a lilac. Blue sapphires are changed to yellow by radium, and yellow sapphires are changed to blue by ultra-violet light. Sapphires become colorless when heated and white sapphires are turned yellow by radium. In other words, in a good many cases, gems become colorless when heated, and the effects of radium and of ultra-violet are antagonistic. There is no known substance which behaves like this when present in mass. Consequently one is forced to the conclusion either that many of the gems are colored by hitherto unknown elements, or that the color is due to colloidal material which behaves differently from the same substance in mass. The second explanation is the more probable one, because we know that ruby glass, which is colored red by colloidal gold, becomes colorless if heated too hot, and the red color changes to blue if the glass is heated moderately for a long time. So far, however, no one has duplicated in the laboratory the color phenomenon shown by the gems and we consequently do not know what the real coloring matter is in many cases.

MEAT AND MILK IN THE FOOD SUPPLY

(Report of the Committee on Food and Nutrition of the National Research Council, April 3, 1920)

IT has long been known, but perhaps never sufficiently emphasized, that the milk cow returns in the human food which she yields, a very much larger share of the protein and energy of the feed she consumes than does the beef animal. Dr. Armsby, probably the leading expert of this country on animal nutrition, has estimated (Science, August 17, 1917) that of the energy of grain used in feeding the animal there is recovered for human consumption about 18 per cent in milk, and only about 3½ per cent in beef.

In an official Report on the Food Supply of the United Kingdom, it is estimated that to produce 100 calories of human food in the form of milk from a good cow, requires animal feed of 2.9 pounds starch equivalent; 100 calories milk from a poor cow is estimated to require the consumption of 4.7 pounds; while to produce 100 calories of beef from a steer 2½ years old it is estimated that 9 pounds of starch equivalent in feed are required.

Stated in terms comparable with those used by Dr. Armsby, this would mean that the good milk cow returns 20 per cent of the energy value of what she consumes, the poor milk cow 12 per cent, and the good beef steer only 6 per cent. Although this estimate is more favorable to the beef steer than is that of Dr. Armsby, yet even in this estimate it will be seen that the poor cow is twice as efficient, and the good milk cow more than three times as efficient as the beef steer in the conservation of energy in the food supply.

Considering the whole length of life of the animal, Professor Wood, the leading English agricultural expert, estimates that the cow returns in milk, veal and beef, 1/12 as much food as she has consumed, while the beef steer returns only 1/64. In other words, the cow is five times as efficient as the beef steer as a food producer when the whole life cycle of the animal is considered. Similarly it has been estimated by Cooper and Spillman (Farmers' Bulletin, No. 817, 1917, U. S. Department of Agriculture) that the crops grown on a given area may be expected to yield from four to five times as much protein and energy for human consumption when fed to dairy cows as when used for beef production. As Wood has very strikingly shown, the longer the time that the beef animals are fattened on grain, the less economical the process becomes.

Quite recently Dr. Armsby has pointed out (Yale Review, January, 1920) that "the dairy cow shows the highest efficiency of any domestic animal, both as regards conversion of food and availabality of the product for man."

Not only is the milk cow several times more efficient than the beef steer in the conservation of proteins, fats, and carbohydrate for human consumption, but in the gathering and preparation of mineral elements and vitamines she contrasts even more favorably with the beef animal. It is largely because of its richness in calcium and in fat-soluble vitamine that milk is the most efficient nutritional supplement to bread or other grain products.

Meat is strikingly poor in calcium and does relatively little to balance a diet consisting largely of bread or of other products of seeds. It does, of course, supplement the protein, but American dietaries would nearly always be adequate as regards protein even without the meat that they contain. On the other hand, dietaries containing little or no milk are very apt to be inadequate as regards calcium. Detailed analysis of the results of hundreds of American dietary studies shows that in practice the adequacy of the calcium intake depends more largely on the sufficiency of milk supply than upon any other factor, or, in fact, than upon all other factors combined.

The vitamines furnished by hay and grains, and thus consumed by cattle, are stored in the animals' tissues to only a limited extent, but they are transferred in relative abundance to the milk. Hence the vitamines of the coarse material of grain, not directly available as human food, are brought into form for man's use very efficiently through milk production, and very inefficiently through the production of meat.

Thus the result of recent studies in nutrition, which have made clearer the importance of the mineral elements, and vitamines, is to emphasize strongly the great desirability of a more abundant milk supply, even if this should somewhat reduce the production and consumption of meat. Our present knowledge of nutrition justifies more fully than ever before the statement that "the dietary should be built around bread and milk," bread or other grain products being the foods which furnish the most nutriment for their cost (whether in money or in land and labor) and milk being by far the most efficient nutritional supplement to bread or other grain products. Therefore somewhat more of our grain crops than is the case at present should come directly into human consumption to augment the bread supply, and of the grain fed to cattle more should be used for the production of milk, and less for the production of meat.

In general, 10 pounds of grain may be expected to produce not over one pound of meat or about three quarts of milk. If the three quarts of milk cost the consumer more (because of greater labor cost in production) they are also certainly worth more to him. In so far as things as different in their nutritional properties as meat and milk can be compared, it is fair to say that one quart of milk is at least as great an asset in the family dietary as is one pound of meat. The per capita consumption of meat in the United States is so high that it might be reduced by one-third or even one-half with little or no nutritional loss, while a corresponding increase in milk consumption would certainly constitute a great improvement in the average American dietary. We are confident that a moderate shifting of emphasis from meat to milk will help in the normal evolution of American agriculture and improve the food economy and public health of the American people.

THE PROPER TIME OF DAY TO GATHER FRUIT.

THE Bureau of Plant Industry of the United States Department of Agriculture has recently published some important information with respect to the hour at which fruit should be gathered, which is by no means a matter of indifference as might be thought. On the contrary its shipping quality has been found to depend upon its temperature when plucked, and this naturally depends upon the time of day. Botanists have long ago known that certain portions of plants are capable of attaining a temperature considerably above that of the surrounding air. During the middle of the day direct sunshine frequently causes a very marked and rapid rise of temperature in small fruits. This fact was noted by Messrs. Stevens, Neil and Wilcox with respect to huckleberries in 1916, and inspired fresh researches especially in 1918, with respect to other fruit.

The method of investigation was as follows: Specimens of the fruit mentioned were gathered hourly between the hours of 6 A. M. and 7 P. M. on sunny days and placed in baskets, each containing about one liter. After each collection of fruit a thermometer was placed in the middle of the basket among the mass of fruit and the temperature noted while at the same time the external temperature was registered by a control thermometer. The absolute figures are of but small importance but interesting deductions may be derived from the differences noted at the same hour between the figures recorded by the two thermometers. The extreme difference noted varied in amount and in the time when recorded according to the kind of fruit. But the maximum difference was always registered betwen 10 A. M. and noon.

In the case of strawberries it was 9.5° C. at 12 M.; for a variety of currants it was 9.0° C. at 12 M.; for another variety of currants, 6.5° C. at 10 A. M.; for the gooseberry it was 4.5° C. at 10 A. M.

The minimum difference of temperature, on the contrary, always occurred in the morning and evening, and was almost nil during the night. An effort was also made by inserting the bulb of the thermometer into the pulp of the fruit to discover whether there was an appreciable difference in temperature between the center of the fruit and its outside, but this difference was usually found to be extremely slight. These experiments have as their object the determination of the reason why lots of fruit gathered in the same gardens at the same season, only a few hours apart and in practically the same conditions of weather, sometimes arrive at market in a very different condition, although packed and shipped as soon as gathered in all cases, and after the same number of hours of travel.

Records kept for fifteen years with respect to peaches (a very fragile fruit) have shown that peaches gathered in the middle of the day usually bear shipping badly and we are forced to the conclusion that the keeping qualities of small fruits depend upon their temperature when gathered.

Consequently, horticulturists are advised to avoid the hot hours in the middle of the day for gathering fruit, particularly upon sunny days. In cloudy weather the hour of gathering is of less importance. The early hours of the morning, after the comparative coolness of the night are best of all. Contrary to what one might think it is far better, in case the train upon which the fruit is to be shipped does not reach the nearest station until midday, to gather the fruit early and keep it properly wrapped in baskets in the shade, rather than to leave it upon the trees until 10 or 11 o'clock with the idea of shipping it that much fresher.

Research Work of the United States Bureau of Standards

Notes Specially Prepared for the SCIENTIFIC AMERICAN MONTHLY

THE IMPORTANCE OF SPARK PLUGS.

THE importance of the ignition system in the operation of internal combustion engines is known to all users of automobiles, but only recently has such apparatus been subjected to scientific investigation.

During the war, it was discovered that the faulty operation of airplane engines appeared to be due very often to the improper functioning of the ignition system and particularly the spark plugs.

The importance of the problem was such that the Bureau of Standards was asked by the National Advisory Committee for Aeronautics, in November, 1916, to undertake a study of the causes of failure of spark plugs, and to develop, if possible, a superior type of plug. It was apparent that a great deal of the trouble in spark plug operation was due to the use of an imperfect insulator and the Bureau's efforts were, therefore, largely directed towards the perfecting of a more satisfactory form of spark plug porcelain. The program which was finally adopted consisted in the making of a large number of samples of insulators by the Ceramic Laboratory of the Bureau which were then tested for their electrical properties by the Electrical Division of the Bureau.

As a result of this work, an insulator was produced which proved in laboratory and service tests to be superior to any heretofore used. The formula for its composition was given to the manufacturers and spark plugs using it are now being produced commercially.

The methods of testing spark plugs are based on service requirements. To be perfectly satisfactory, a spark plug ought to be able to cause a spark to pass between its points under the worst conditions existing in the engine cylinder. This requires that the insulation between the central electrode and the outer shell of the plug shall maintain its non-conducting properties throughout a wide range of temperatures and when covered with oil or carbon. The voltage across the gap must be high enough to cause the passage of a spark through the highly compressed gas in the cylinder and sometimes even when a drop of oil adheres to the sparking points; likewise the plug must be gas-tight.

It is perhaps not generally known that while the actual leakage of gas through a faulty plug is not large enough to appreciably affect the power developed by the cylinder, it does cause rapid deterioration of the plug itself, due to the overheating and subsequent breakdown of the insulator. Absolute gas-tightness is, therefore, one of the essential requirements of a satisfactory plug. Besides the requirements above outlined, a plug should be easy to clean and this requires that it be simple in construction and readily taken apart.

Many commercial spark plugs which possess excellent properties along one of the above lines are defective in some other respect, so that as a whole the service which they render is not satisfactory.

The tests carried out by the Bureau of Standards included ones to determine the electrical resistance of the porcelain insulators under various temperature conditions, the gas-tightness of the plugs, and their ability to stand up under mechanical shock, beside actual tests under operating conditions in engines.

For the electrical tests of the porcelain, the actual insulator or a special cup-shaped specimen made from the insulating material was placed in a small furnace in which it was heated to a high temperature while at the same time the insulator formed part of an electric circuit. The temperature at which the material ceased to be an insulator under the given electrical conditions was thus determined. The tests upon the cup-shaped specimens are, in general, more satisfactory than those on the finished insulators, as the conditions may be more readily controlled.

In order to determine the gas-tightness, the complete spark plugs were screwed into a steel pipe connected with a source of compressed air. This pipe was immersed in an oil bath heated by electricity. If the plugs leaked under the air pressure, bubbles appeared at the surface of the oil. A graduated bell jar was placed over each plug and the displacement of the oil by the air in a given time could thus be determined. In this way, the leakage of completed plugs could readily be calculated..

A special machine was constructed for determining the resistance of spark plugs to mechanical shock. It consists essentially of a hammer into one side of which the spark plug is screwed. This hammer is dropped through a definite height upon a steel anvil by means of springs and a revolving cam mounted on a shaft and driven by a small motor. The blow was repeated a fixed number of times per minute and the spark plug which stood up the longest under these repeated shocks was considered to be the strongest mechanically. No laboratory tests can, of course, ever be as satisfactory as actual service on an engine in determining the suitability of such a device as a spark plug. This was recognized by the Bureau and the engine tests which it conducted were very complete.

In connection with the engine work done in the altitude laboratory, it was possible to investigate the behavior of spark plugs under the actual conditions met with in flight at high altitudes. Plugs were also tested in airplane engines under ground conditions and in typical automobile engines. Several reports have been issued on this subject in connection with the National Advisory Committee for Aeronautics and have been combined in the Fourth and Fifth Annual Reports of that Committee.

THE TESTING OF AIRPLANE RADIATORS.

LIKE the ignition system, the radiator is an extremely important portion of the aircraft power plant. It is true that a considerable number of such engines are air-cooled and thus are able to dispense with a water-cooling system entirely, but the typical airplane engine of today is, nevertheless, a water-cooled machine. There are some difficulties connected with the water circulating systems and radiators used on automobiles and these difficulties are magnified many times in the case of an airplane. The speed of the average motor car is not sufficiently high to warrant the making of any great effort toward reduction of wind resistance. If the radiator will cool the circulating water sufficiently to keep the engine at a proper working temperature when the car is moving at an ordinary rate of speed, it is all that is necessary. These requirements, simple as they appear, however, necessitate some care in the design of the radiator. They require the exercise of the highest degree of skill and the use of all the available information on the subject when it comes to the designing of a successful radiator for airplanes.

On air craft the elimination of every ounce of superfluous weight is of the first importance. This has resulted in the use of engines which deliver a very great amount of power for their size and necessarily results in an engine operating at high temperatures. The cooling of such an engine is in many respects a difficult problem even if it had to be accomplished wholly under the normal conditions existing at the earth's

surface. To successfully accomplish it, both when the plane is flying near the earth and when it is operating at high altitudes and low temperatures, requires, as before stated, the highest degree of skill. Then, too, the modern airplane travels at a very high rate of speed, often well over 100 miles per hour, and every bit of unnecessary head resistance ought to be avoided. It is probably not generally known that an unsuitable type of radiator, perhaps badly located on the plane, will absorb from 10 to 20 per cent or more of the total power of the engine, and where every bit of power should be made available for useful work, this is a serious loss.

Early in the war, it was evident that many types of radiators, not well fitted by design and construction for use on airplanes, were being employed on our machines. It was with the idea of discovering, if possible, the most suitable type of radiator for military airplanes that the Power Plants' Committee of the National Advisory Committee for Aeroanutics requested the Bureau of Standards to thoroughly investigate this problem. This work has been continued from May, 1917, when it was commenced, to the present time, and a great deal of extremely valuable data have been collected.

The Bureau has used in this work three types of wind tunnels and has received from the various radiator manufacturers over 100 specimens of their products. One of the wind tunnels is the large 54-inch tunnel constructed about two years ago. This tunnel is provided with two aerodynamical balances, one of which is rugged enough to serve as a mounting for specimens of radiator core. Within this tunnel have been determined the head resistance of the various specimens submitted. The flow of air through the radiators in terms of speed of the air stream has likewise been determined in this tunnel. The securing of this information was attended with considerable difficulty, but by means of a special small sized Venturi tube attached to the rear face of the radiator, it was successfully accomplished.

The two other tunnels are of small size and were used for the determination of the efficiencies of the radiators as cooling devices. The first of these tunnels which was constructed consisted of an air-tight tank within which was mounted a smaller wooden air passage open to the tank at both ends and in the center of which the specimen radiator core was placed. The same air was continually forced through the radiator and returned along the interior of the outer tank by a blower driven by a belt from an electric motor. As the entire outer tank was air-tight, the air could be withdrawn from it by means of a vacuum pump to simulate the low atmospheric pressure met with at high altitudes. Through the radiator core hot water was forced by a centrifugal pump and the rate of cooling of the water at a given air speed was thus determined. The air within the tank was cooled between each successive passage through the radiator, by means of a honeycomb mounted at one end of the wooden air duct. This tunnel was rather difficult to operate as a run required a number of hours due to the fact that it was a long while after the starting of the motor before stable conditions were reached within the tank. The second small tunnel was, therefore, built. This was entirely open and consisted merely of a wooden box-like structure, the passage through which was blocked by the radiator core. At one end of the air passage thus formed, a blower was placed serving to draw the air through the radiator. Instead of using water in the radiator core, superheated steam at atmospheric pressure was employed. It was found that the heat transfer could be determined as accurately through the use of steam as when using water, and a test could be carried out with this apparatus in a very much shorter time.

Through these tests on head resistance, air flow, and heat transfer, it has been possible to state what should be the principal characteristics of a satisfactory airplane radiator. It is obvious that low head resistance and high heat transfer are necessarily conflicting requirements and the most successful type of radiator to employ is the one which hits the happy medium between these two opposite extremes.

The Bureau has been able to assign a so-called figure of merit to each type of radiator tested. This figure of merit expresses the horsepower dissipated by the radiator in terms of the horsepower absorbed, and, therefore, states in briefest possible form the suitability of the devices for airplane cooling purposes. The results of the Bureau's work in this field have been included in the series of Aeronautic Power Plants Reports issued jointly by the Bureau of Standards and the National Advisory Committee for Aeronautics, and have been well received by most of the manufacturers of radiators. While particularly applicable to aircraft work, many of the facts discovered are of importance to the designers of this class of apparatus for motor car and other uses.

A NEW FORM OF VIBRATION GALVANOMETER.

VIBRATION galvanometers are very useful in a. c. null measurements, but have not been much used in industrial laboratories on account of their being sensitive to external vibrations and requiring delicate adjustments. The present instrument, which has a sensitivity higher than other forms of the moving-iron type, but less than that of the most sensitive forms of the moving-coil type, has the advantages of sturdiness, quick responsiveness, and freedom from the effects of external vibration. It consists essentially of a fine steel wire mounted on one pole of a permanent magnet and so arranged that the free end of the wire may vibrate between the poles of an electromagnet through which flows the current to be detected. The motion of the wire is observed with a microscope.

The "resonance range" is about one per cent; that is, if the frequency of the current is one per cent above or below the frequency of resonance the amplitude of vibration will be half as great as resonance. The sensitivity is such that with a 1-ohm winding an e.m.f. of 3 microvolts may be detected, and with a 270-ohm winding a current of 0.05 microampere can readily be detected.

TWELFTH ANNUAL CONFERENCE ON WEIGHTS AND MEASURES, 1919.

THE Annual Conference on Weights and Measures is a national organization composed of State and local weights and measures officials throughout the United States. This body meets annually at the Bureau of Standards, Washington, D. C., for the purpose of discussing and solving problems relating to weights and measures, such as uniform legislation, rules and regulations and methods of enforcement of weights and measures laws, specifications and tolerances for all commercial apparatus, and the proper inspection and test of apparatus, etc. The present meeting was the twelfth one held, and the first since 1916, the sessions having been discontinued during the war. This report, which is a stenographic record of the proceedings, includes all papers read and resolutions adopted. Perhaps the most important single accomplishment of this Conference was the discussion upon and the tentative adoption of a set of specifications and tolerances for liquid-measuring pumps, especially those used in the sale of gasoline, kerosene, etc. It was agreed by the members that these should be thoroughly studied and tried out in the field and that final action upon them should be taken at the next meeting. The unsatisfactory condition of liquid-measuring pumps in all parts of the country rendered action on this important subject imperative if the purchaser was to receive the correct amounts.

Consideration was also given to a number of other subjects of importance, including the progress made in the various States and cities; the necessity of the Federal regulation of type of apparatus; the proper method of sale of ice and wood; the testing of railroad track and mine scales; the marking of wrapped hams and bacon with the net weight; the standardization of shipping containers; and the adoption of the metric system of weights and measures.

Progress in the Field of Applied Chemistry

Notes Culled from Current Technical Literature

FUMES AND FOOD.

THE statement has frequently been made that much of our industrial research has received its impetus from litigation or legislation which threatened the extinction of noxious waste-producing industries. In the vicinity of certain smelters co-operation among the farmers brought about a series of damage suits based upon injury to crops by smelter fumes, largely compounds of sulphur. A long series of experiments has convinced the smelter authorities that certain crops are damaged by the fumes, although in this case, as elsewhere, plots of the same material growing side by side were not always similarly affected by the sulphur fumes.

It has been known for some time how to utilize such fumes, as for example, in the manufacture of sulphuric acid, and had the smelters been located near the large consuming markets, this opportunity to make sulphuric acid cheaply would never have been overlooked. It has not been possible to ship sulphuric acid such distances and compete with manufacturers nearer the market.

A plan has been evolved, however, which seems to afford the long-desired solution. There are great deposits of phosphate rock to be found sufficiently near these smelters to allow it to be laid down at the plants for not over $5 a ton. In making super-phosphate fertilizer the usual practice is to use a ton of rock and a ton of sulphuric acid, producing two tons of super-phosphate. This material is sold on the basis of the available phosphate content and the treatment just mentioned does not produce an amount of phosphate which will stand the same long freight haul which makes the manufacture of sulphuric acid itself uneconomical at those points. By using a much larger quantity of acid the reaction with the phosphate rock can be carried to the point where syrupy phosphoric acid is produced and since the smelters can make sulphuric acid at a price reported to be about $5 a ton, they can of course use the large quantities necessary to carry through this last-named reaction. Now if a further quantity of phosphate rock is treated with this syrupy phosphoric acid, a double super-phosphate is produced which runs so high in posphate that it will stand transportation charges to carry it to a world-wide market.

There is a great demand for phosphates in Europe and in the Orient, as well as among our own agricultural states, and it would appear that the fumes which have long been a nuisance may now make possible the utilization of rich phosphate rock deposits which in turn will produce a marked increase in the world food supply.

THE ORGANIZATION OF INDUSTRIAL SCIENTIFIC RESEARCH.

THE McGraw-Hill Book Company, Inc., has just published "The Organization of Industrial Scientific Research" by Dr. C. E. K. Mees, who has long been concerned in the study of such organizations and in putting into effect the results of this study. The book is intended to answer practical questions of the manufacturer who, having been convinced that the application of science is necessary for the progress of his business, desires to know the probable cost to establish and maintain such a laboratory, where a suitable staff can be secured, the lines of work that should be pursued, how soon and to what extent returns may be expected, how the laboratory should be organized, and what place in the established organization the new department should occupy. The book discusses the general question of research and how it should be conducted, its purposes and some of the results which have come from research, and then gives particular attention to types of research laboratories, coöperative laboratories, the position of the research laboratory in an industrial organization, the internal organization of industrial research laboratories, the staff of research laboratory, the type of building and how it should be equipped, and suggestions as to the direction of the work of such a laboratory. The entire discussion is illustrated with organization charts and diagrams which are very useful and serve to emphasize the points made in the text. As an example of how the principles discussed work out in practice, a chapter is devoted to the design of a research laboratory for a specific industry. Finally there is an extensive bibliography and an author's index, as well as an index of laboratories to which reference is made in the text, all of which will be found very useful.

A book of this character coming, as it does, from the head of a great industrial research laboratory, is welcome at this time when the establishment of research organizations and laboratories throughout the world is being taken up so seriously. There are a few men who have likewise studied this same problem, who are capable of giving sound advice on the subject; but we have had no adequate printed discussion previous to the appearance of this work, and it is to be expected that manufacturers in general will find in it a great deal of interest, helpfulness, and value.

PHOTO-CHEMISTRY.

THOSE who attended the lectures of the Eighth International Congress of Applied Chemistry will always remember the delightful and interesting lecture upon photo-chemistry by the Italian representative. The part which light plays in a host of chemical reactions has long been recognized, but not until recently has anyone ventured the statement that light has a more profound effect upon the growth of plants than does temperature.

W. W. Garner and H. A. Allard, scientists in the Bureau of Plant Industry, U. S. Department of Agriculture, have conducted exhaustive experiments which may prove of the highest importance in the future planting of crop systems for different regions eventually based no doubt upon the world requirements for food stuffs. It may even be found that the animal organism is also capable of responding to the stimulus of light, and experiments which have been conducted upon hens with artificial light may prove eventually to have been founded on much better scientific bases than the humorists have led us to believe.

Greenhouse experiments, according to an announcement of the Department of Agriculture, prove that the flowering and fruiting period of practically any plant can be made to take place at any time of the year by lengthening or shortening the day, as may prove to be required. This may be accomplished by darkening the house in the morning and evening to obtain a short day, or artificial light may be used to lengthen the period of light.

Heretofore we have considered temperature as the controlling factor deciding which were the spring flowers and to bring about the migration of birds, but it now seems that such phenomena may be a function of the length of the day. It has been found that some plants will not reproduce except when exposed to the favorable length of day, although too much day light for flowering and fruiting might stimulate profuse vegetable growth. When a length of day well suited to both growth and fruiting obtains, then we have the everbearing type of plant. The scientists quoted have forced cer-

tain plants to complete two cycles in one season and soy beans, exposed to the light for only five hours a day, flowered nearly three months earlier than plants left in the light all day. They attained only one-eighth the height, however. Iris kept in artificial light for eighteen hours a day bloomed in two months.

The new principle may explain why many plants grow so successfully near the northern limit of their range. In such latitudes the long day permits maximum vegetative growth, after which the short day intervenes and starts reproduction. That temperature seems to exert on the whole a far less influence is shown by the fact that plants kept in the dark for a part of the day could be made to undergo the changes of autumn in mid-summer, notwithstanding the fact that frequently the temperature of the greenhouse was higher than that outside.

Scientists have frequently been puzzled by the behavior of crops attempted in locations new to the plant, and it would seem that this influence of light may have been a factor of great importance to which full consideration was not given.

The chemist in his laboratory frequently reckons with light in conducting his experiments and apparently nature in her laboratory finds the need even more urgent. What a tremendous scope for new research is opened by these latest discoveries in photo-chemistry!

NAMES OF DYES.

IN a recent number of the *Color Trade Journal*, Dr. J. M. Mathews describes in detail the basis for the present complicated nomenclature of dyestuffs and as synthetic dyes have come to occupy so large a portion of our attention, it may be well to give an outline of the evolution of these names.

In the beginning practically all dyes were given names intended to indicate some particular quality, such as fuchsine, malachite green, etc. Occasionally a color was named for some historical character, giving us Victoria blue and Bismarck brown. About the same time it became the habit to indicate by the name something of the use of the dye-stuff, and we have cloth red, chrome black, and acid magenta. The chemical nature of dyes soon became indicated by the name assigned, some of them, such as tartrazine, denoting the derivation, which in this case is from dioxy-tartaric acid. Methyl violet, diazo black, and azo rubine are examples.

As the number of synthetic dye manufacturers increased, they began to give very different names to the same product, in the hope that they might establish a proprietary or trade name which would be of value to them. For example, there are at least seven names for direct cotton blue, each name indicating a different manufacturer; the dye-stuffs are practically identical. Such a system could not fail to lead to great confusion and this has increased until manufacturers have now endeavored to systematize nomenclature by giving class names to the various lines of products. Thus, the sulphur dyes have received special class names as follows, each indicating a different manufacturer; sulphur colors, immedial colors, thiogene, katigen, kryogene, and thion. All of these are of German origin and the number has been increased by the establishment of new dye houses in Scotland, England and America. We now have Erie colors, pontamine colors, amanil colors, auwico colors, etc.

We frequently find numerals and letters occurring after the names of dye-stuffs, these being private marks used by the manufacturer in identifying the color. These frequently refer to the particular shade. Thus, B indicates a blue tone, R, a red one, G, green, and Y, yellow. Methyl violet B and methyl violet BB or 2 B, would indicate that the last-named is somewhat bluer in tone than the former. Acid yellow G and acid yellow R shows that the foremer has a greenish tone, while the red in the second gives more of an orange shade. X is used to indicate concentrated type. Then, we have W as the sign of a wool dye, S to indicate ready solubility, and L a type of dye fast to light. Where numerals are used, they indicate differences in strength. Auramine O means the pure strong type, while Auramine 1, 2 or 3, refers to dyes more and more dilute.

This would seem to be complication enough, but mixed dyes add another chapter. Thus, a green dye may have been made by properly mixing a yellow and a blue, each of which already had names of their own. Formyl blue B is a bright blue dye-stuff derived from formyl violet S 4 B, with a second dye so chosen as to give the desired blue in the final mixture. These mixed dyes have been necessary in order to meet the demand of the dyer who works largely from a standard color card.

The nearest attempt to a real classification and system of dye nomenclature is represented in dye-stuff tables compiled by Schultz, the last edition of this work being in 1914. There are of course many dyes which cannot be found in these tables, but they represent an effort in the right direction and eventually we may have some satisfactory scheme for identifying and maintaining familiarity with the large and ever-increasing dye family.

ANALYSIS BY ELECTROLYSIS.

A METHOD for determining the percentage of carbon in steel, dependent upon the change of electrical resistance brought about in a standard solution by the precipitation into it of another substance, has been devised by J. R. Cain and J. C. Maxwell. It is claimed that the method is accurate to within .01 per cent. The substance precipitated in the standard solution is in this case the carbon dioxide obtained by the direct combustion of the steel. The standard solution is barium hydroxide of known electrical resistance. The equation involved is barium hydroxide plus carbon dioxide equals barium carbonate and water, and the increase in the resistance is due to the precipitation of the barium as carbonate. This principle is said to be new and the apparatus used is also unique. The method seems to offer many advantages for technical work over the methods heretofore employed for the measurement of electrolytic resistance. Former methods require a complicated and expensive set of apparatus, while the new method is much simpler. The nomograph is used for the graphical representation of the resistance data and the use of special conductivity cells with adjustable electrodes to facilitate the manufacture of any number of such cells without the same cell's being constant, is a new feature. The method is described in a recent issue of *Iron Age*.

GREASE RECOVERY.

THE attention of many chemists has been turned toward the recovery of grease from various waste materials, usually by the solvent extraction process. The treatment of trade or municipal effluence containing grease is always a matter of economic interest and value, especially where wool textiles are manufactured. Doubtless a large part of the oils and fats used in the form of soap might be recovered from the sewage of towns, especially those in textile districts. There is a further waste of animal fats from kitchens and in the city of New York, where garbage has been sorted and graded with a view to the recovery of fats, revenue was produced even in pre-war times.

The solvent extraction process applied to oil cake of seed-crushing mills, has given us the second and third grade oils, but it has not been so extensively used on sewage and where other low-grade oils and greases might be recovered. Grease of this character has been recovered by acidification and steam pressing of the resultant magma, but independent reports now show that even this process has been carried on very indifferently in most instances. There appears to be one principle upon which the efficient and thorough extraction of grease may be said to depend, and that is by the use of a volatile solvent, which can then be recovered for re-use by the employment of a satisfactory still.

In England the process is carried on as follows: "Having

carefully arranged the perforated plates and canvas, the bottom door of the extractor is closed and jointed upon the extractor body. A charge of dry material is then fed through the top manhole into the extractor, and the manhole door carefully secured upon the jointing. The quantity of material which can be worked at a charge in a given extractor has been found to vary with the nature of the material. If the material contains a large proportion, say, 45 to 55 per cent, of mineral matter, such as sand and dirt, it is possible as a rule to work with an extractor 8 or 9 feet in depth and to have almost thorough extraction, because of the openness and stability of the material.

"With a material containing 25 per cent of mineral matter and a large quantity of organic matter in addition to grease, it may only be possible to work with a depth of 4 to 5 feet of material. This is because the material when saturated with the solvent tends to disintegrate and settle down into a compact mass upon the perforated plates, which, if a great weight of material is used, become choked, with the result that the upward circulation of the solvent and the passage of the grease downward into the bottom portion of the extractor are prevented, thus causing very indifferent extraction to occur. With material of this character it is necessary that the diameter of the extractor should be large in comparison with the height, so that the pressure of material on the perforated plates is not too great.

"The next operation is to run a volume of solvent, 100 to 150 gallons, from the storage tank into the lower portion of the extractor. Steam is then gradually turned into the closed coil and the solvent gently evaporates, rising through the perforated plates into the material and finally through it into the condenser. The liquid from the condenser then passes onward through the separator, the solvent returning to the storage tank. In this manner the whole mass of material becomes heated and saturated with solvent, and there is then a continuous percolation of grease dissolved in the solvent downward through the perforated plates and into the lower part of the extractor.

"Fresh supplies of solvent are admitted from the storage tank to the extractor from time to time, so that a steady stream of liquid runs into the separator. This process is continued for 6 to 10 hours, according to the weight and nature of the material; by this time practically the whole of the grease will have been brought down into the lower part of the extractor. Further additions of solvent are then discontinued, and the steam coil is gradually turned on full until the flow of solvent from the condenser almost ceases. The lower part of the extractor then contains a saturated solution of grease. This is next removed to the still by closing the vapor valve on the extractor and admitting a little open steam until a pressure of 2 to 3 pounds is shown on the gage. The valve on the pipe connecting the extractor to the still is then opened, and the grease solution is forced by the pressure from the extractor to the still. If the material is rich in grease, this blowing-out process may have to be carried out two or three times during the extraction process, as well as at the finish."

ENAMELLED APPARATUS.

IN the journal of the American Ceramic Society, Mr. Emerson P. Poste discusses the manufacture of enamel-lined apparatus. It is difficult to estimate the importance of this class of material, not only in the chemical manufacturing plant and laboratory, but in the hospital and household. There are several rather distinct lines of manufacture, some of the iron shapes being coated with a vitreous enamel, built up by several coats, such as a ground coat and cover coats, and the glass-lined material now to be found in the form of tanks and more intricate shapes.

There is great need for technical control not only in the manufacture and application of the enamels, but in the preparation of suitable shapes upon which to place these burned enamels. Obviously over-burning and under-burning must be avoided. There are many questions of coefficients of expansion, uniformity of burning, etc., that are particularly important.

Enamels are usually made up on molecular formulas, and the article mentioned indicates a number of typical formulas. The raw materials which enter into the type of enamel usually placed upon a cast-iron or pressed steel shape may contain various proportions of some of the following: soda, borax, saltpeter, Chile saltpeter, lead oxide, zinc oxide, tin oxide, calcspar, barium carbonate, magnesium carbonate, feldspar, fluorspar, cryolite, quartz, manganese dioxide, and cobalt oxide. In addition, clay or sand is sometimes added in the mill in which the frit is ground.

The growth of the chemical industry has introduced many new problems in the manufacture of enamel-lined apparatus, for acid-resisting enamels must be used in apparatus to be provided with various complicated connections, stirring apparatus, and similar unusual equipment.

REFRACTORY MATERIALS FOR COKE OVENS.

THE *British Clay Worker* gives some specifications relative to refractories suitable for coke oven construction. The special qualities required are: resistance to high, prolonged heating, either under normal or increased pressure; resistance to mechanical abrasion; resistance to sudden changes of temperature; impermeability to gases; and resistance to chemical attack, especially by sodium chloride at high temperatures. Fire clay brick are extensively used in England, because washed coal is fired into the retorts and this contains about fifteen per cent moisture. Fire clay brick are more resistant to moisture than are silica brick. In the United States the coals are either not washed or are partly dried after washing, and usually contain not more than five per cent of moisture, so that silica brick, which are superior in heat conductivity to fire brick, are used. The fire clay brick used in coke ovens contain a higher per cent of silica than most fire clays and are made by mixing a siliceous material with a high-grade fire clay.

In a satisfactory brick the silica content will not be less than eighty per cent, while ferric oxide should not exceed two per cent. The total alkali should be less than 1.3 per cent, with the lime and magnesia about 0.5 per cent.

Fine-grained material is generally less satisfactory than the coarser grained, and is less resistant to chemical attack. Coarse-grained material also withstands sudden changes of temperature better, and grain size obviously affects porosity, permeability, and heat conductivity. The finer grained refractories on the whole withstand mechanical abrasion the best.

By washing the coal with hot water most of the soluble salts, such as sodium chloride, are removed and the life of the refractory is thus prolonged. The fluxing effect of coals has been tested by heating pieces of fire clay in a small crucible with samples of the various coals. The fire clay is then washed free from the soluble salts and the percentage of alkali reckoned as potassium oxide determined, making due allowance for that present initially in the fire clay. In every instance the experiments with unwashed coal yielded a higher percentage of alkali in the clay and similar experiments to determine whether moisture favors the action of salts on coal show that it does materially increase such action.

UNSOUNDNESS IN CEMENT.

THERE has been considerable discussion in *Concrete* relative to the cause of unsoundness in Portland cement. According to the observations of R. K. Meade, an authority, it is difficult to make sound cement from raw material high in iron. Excess of fluxes is of little assistance in producing sound cement and the free lime in the porous clinker should hydrate in the 24-hour storage period of the test pat. It is the belief of Mr. Meade that neither the free lime theory nor the dusting clinker theory are entirely acceptable. The dusting clinker

is usually produced by a relatively high silica mix. High lime cements are very apt to be unsound and they also have the greatest quantity of cohesive constituents. Gypsum, plaster of Paris, or calcium chloride, added to the cement, often make it sound and concrete may become sound with age. As the author observes, many of the theories on cement are unsatisfactory, because while they explain some phenomena quite well, they fail entirely in the case of others.

PULVERIZED COAL.

IN the last issue of *Chemical Age*, under the title "Forecasting the Fuel of the Future," there is an interesting discussion of pulverized coal and its application. Many fields of usefulness for this grade of fuel were found: first, where in any one installation the fuel consumption is at the rate of not less than eighty tons a day; second, where an inexpensive source of low-grade fuel is available; third, where the character of the coal is such that it cannot be efficiently handled in the ordinary way, either because of its size or friability; fourth, where operating practice requires special facilities for heat control; and fifth, especially where gas is available for use with pulverized coal when peak-load conditions must be met.

The factors which have to be taken into consideration when burning pulverized coal in suspension are a sufficiently low velocity of fuel travel through the combustion zone in order that the complete reaction may take place, a refractory furnace which will assist in maintaining a proper temperature, the admission of air containing free oxygen, and the disposition of the gaseous products of combustion and of the ash. Any coal reduced to particles of a size to promote quickly the chemical reaction which we call combustion, and then passed through a zone of the right temperature, will burn satisfactorily in suspension, and this makes possible the efficient utilization of a great quantity of low-grade fuel which heretofore has not been drawn upon very extensively.

The principal points in the pulverizing of coal are given as follows: From the storage hopper coal is fed into a crusher that will produce lumps passing a three-quarter by three-quarter inch screen or smaller. The lumps are then passed over a magnetic separator, which removes stray iron which might cause trouble in the pulverizing equipment. The coal thus cleaned is stored and dried on its way to a dry coal storage bin, from which it feeds by gravity to the pulverizer. The rate of feed is controlled to prevent flooding the pulverizer, and after pulverizing, the coal goes again to a storage bin located as nearly as possible to the point of ultimate consumption. It is to be seen, therefore, that the installation is a series of reservoirs, each of which should have sufficient capacity to permit operation irrespective of what takes place in the set of equipment immediately preceding it.

In the cement industry many millions of tons of pulverized coal have been handled by means of screw conveyors without damage and we must realize that pulverized fuel in mass is neither explosive nor highly combustible, and that danger is encountered only when, like other readily oxidizable dust, it is in suspension in air.

AMERICAN DRUGS.

IT is well known that we have depended upon the importation of crude drugs for nearly all of those used in pharmaceutical preparations. Comparatively little consistent work extending over long periods has been undertaken either with the purpose of introducing foreign drugs or of so improving domestic varieties that their potency could be increased. There have been a few exceptions to the general apathy toward American grown drugs and at the University of Wisconsin a pharmaceutical experiment station has been established.

The cultivation of medicinal plants for other than instructive purposes was begun there in the spring of 1908. Since then a number of other universities have begun the cultivation of medicinal plants with reference to their economic aspect and more lately, the cultivation of such plants on a commercial scale has been undertaken by certain pharmaceutical manufacturers. Another experiment embracing some twenty acres has been established under the auspices of the Institute of Industrial Research, where both the introduction of foreign medicinal plants and the improvement of domestic plants has been under study.

The experiments at Wisconsin are carried on in coöperation with the Federal Government, the state, and are supported by fellowships. Besides plant-breeding experiments and the growth of a considerable number of plants, experiments have been conducted with reference to distillation and other processes for obtaining values from the various crude drugs.

On the whole the possibility of providing several of the much needed drugs has been established, and the time has come when such experiments deserve extensive encouragement and substantial aid.

ZIRCONIUM.

THE unusual properties of zirconium and its compounds make the element an unusually attractive one for research and experiment. Zircite is being extensively used in refractories, especially unusual types of furnace linings and tubes for pyrometers. Ferro-zirconium is proving of unusual interest in the steel field now that it has been determined that zirconium and its alloys dissolve completely in the molten steel. The ferro-zirconium thus obtained has a very high strength and possesses qualities which make it desirable in the manufacture of armor or similar sheet metal for defensive purposes.

A recent number of *Foundry* quotes *Le Genié Civil* as follows.

"Armor made of nickel-zirconium steel having a thickness of 0.39 inch has shown the same resistance to the bullet as nickel molybdenum steel of 0.51 inch thickness or chromium steel of 0.63 inch thickness. The zirconium steel which has given the best results has the following composition. Carbon, 0.42 per cent; manganese, 1 per cent; silicon, 1.50 per cent; nickel, 3 per cent; zirconium, 0.34 per cent. It possesses a tensile strength of 250,000 pounds per square inch."

LOSS OF NUTRITIVE PROPERTIES IN CANNED GOODS.

IN preparing vegetables for canning the preliminary process of boiling, even though it may last a very short time, inevitably extracts a portion of the most soluble and most appetizing nurtitive principle. Recent experiments have been made, both at Waedenswill in Switzerland, and at Dahlem near Steglitz in Germany, with carrots, peas, beans, spinach, asparagus and cauliflower, to determine the percentage of loss and the best method of avoiding or reducing it. The conclusions arrived at in the two countries are in agreement and are thus summarized in the *Vie Agricole et Rurale*.

It is found advisable to complete the preliminary boiling or "blanching" *in as short a time as possible*, and to employ for this purpose an *autoclave* instead of steam. The percentage of loss of the dry extract amounts to from 5 to 15 per cent in boiling water, from 2 to 8 per cent in steam and only from 1 to 7 per cent in the autoclave. The pressure in the latter is only a quarter of an atmosphere and the period of boiling lasts for only a few minutes—a quarter of an hour at the most. The loss of nutritive matters is increased by the fact that upon being taken from the boiling water the vegetables are placed in cold water and sometimes even in running water.

It is advised that the first water in which the vegetables are boiled should not be thrown away but used to fill the cans before sterilization. It has also been suggested that the cold water in which the vegetables are steeped might be used in the autoclave so as to entirely avoid the loss of the most soluble and most delicate matters. In any case these liquids may be concentrated and used for making condensed soups with the addition of fats, and either milk or meat products.

Progress in the Field of Electricity

Summaries and Excerpts from Current Periodicals

SPARK GAPS.

In practice high alternating pressures are often measured by means of spark gaps; in most cases, especially when point electrodes are used, the relation between voltage and gap length must be determined experimentally on account of the luminous discharges from such points and leads. However, in case of cylindrical or spherical electrodes the sparking voltage may be expressed in terms of the dielectric strength of the air and of the dimension of the gap. By proper selection of the diameter of the electrodes the disturbing discharges can be avoided. The fundamental and exact equations of the sphere gap are not suitable for practical applications. These can be simplified by an assumption that the charges on the spheres are concentrated in two points, the position of which is such that they divide the diameter of each sphere harmonically. Then, neglecting the increase of capacity, resulting from the decrease of the electrode distance, we have the following relation:

$F = V\ (A + D)/A\ D$, where V is the potential difference between the spheres, D, their diameter and A, the distance between the spheres. The above relation holds good only for

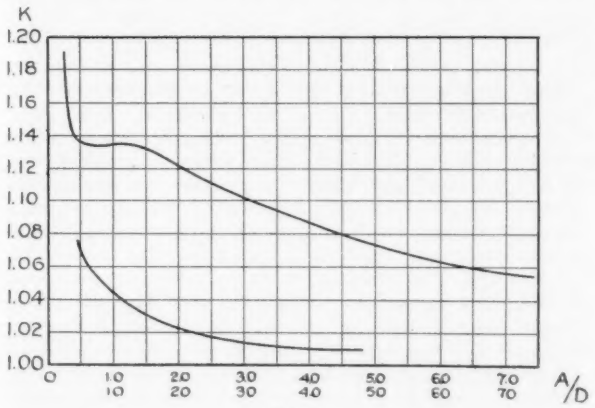

FIG. 1

spheres infinitely far apart; by comparing it with the exact formula of the spark gap a correction factor 1/K is determined which depends only on the relation A/D, and the above relation becomes

$$V = K\ F\ A\ D/A + D$$

The values of K are given in Fig. 1.

The potential distribution in the electric field was studied by immersing the spheres in an electrolyte, thus avoiding the various field disturbances. Spheres were used of 0.3 to 15 cm. in diameter with gap distances from 10 cm. to 40 cm. The experimental results agreed well with the calculated values. This method of investigation allows also of determining the influence of leads. The length of leading in wires of 0.7 mm. diam. was varied from 0 to 50 cm.; it was found that the potential gradient at the surface of the sphere was practically independent of the length of the leads; however the influence of the latter becomes noticeable at a short distance from the surface and is greater in the case of small spheres.

The problem of the sparking voltages between spherical electrodes was investigated by means of a 20 kw. transformer having a ratio of 500/200,000; the voltage was measured on the low-pressure side by a specially designed and well described and illustrated instrument which the author calls an "oscilloscope." It was found that the spark voltage is entirely independent of the wave form and is only a function of the maximum pressure. The values of the spark voltage for the various spheres and gap distances were reduced to normal pressure and temperature on the assumption that the spark voltage varies directly with the atmospheric pressure and inversely with the absolute temperature. From these data the dielectric strength of air in kilovolts per cm. is found to be a function of the sphere diameter and almost independent of the gas, as shown in Fig. 2.

From these data the breakdown voltage of a gap of A cm. between spheres of diameter D may be found from the relation given above. The error is from 1½—3 per cent within the range $A/D = 4$ to ½.—*W. Estorff, Zeitschrift für Instrumentenkunde*, July, 1919, pp. 227-30.

SUBMERSIBLE ELECTRIC MOTOR PUMP.

In the January issue of the Scientific American Monthly we described a new type of electrically-driven pump which is rendering very good service in marine salvage operations. The unique feature of this pump is that the electric motor will work entirely submerged under water and that the whole casing is filled with water while running, thus rendering it peculiarly suitable for use in flooded or damp places, such as mine workings, for example. It is entirely free from the risk of breakdown inherent in all so-called water-tight electric motors which depend on the efficiency of the joints and

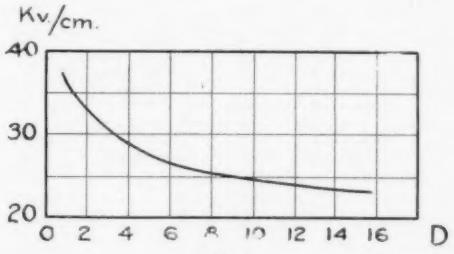

FIG 2

glands in the cases or tanks in which such motors are enclosed.

Recently some interesting operations have been successfully carried out in Cheshire, mainly with the object of demonstrating the possibilities of this pump for mine work. These operations consisted at first in the unwatering of an abandoned mine-shaft. The plant consisted of two 4-in. submersible motor pumps, each of which had a rated output of 370 gallons per minute at 80 feet total head. The delivery side of one pump was coupled to the suction side of the second pump, thus forming the equivalent of a two-stage centrifugal pump capable of a lift of 160 feet. The electric power was supplied by a portable generating set. Armored flexible rubber hose was used for the pipe line.

In another case three shafts linked together by workings had the water level 11 feet from the surface, and it was desired to lower the water to about 300 feet. In this case the power was supplied from the near-by company power plant. Four 6-inch submersible motor pumps were used, each having a rating of 740 gallons per minute at 75-foot head. They were coupled in pairs, the first pair being lowered to a depth of about 310 feet and the second pair to 150 feet. Steel tube was used for pipe line. After pumping continuously for five days

the water level was lowered to 160 feet and after a further seven days to 275 feet. Instructions were then given to throttle delivery and maintain a constant level at this depth, and readings taken of the inflow which commenced at 47,000 gallons per minute and dropped to 33,000 after three days. Altogether the plant was running for 37 days, one pair of pumps running for 24 days on end and on 19 of these days for the whole of 24 hours. The total quantity of water pumped was 33,623,604 gallons. This novel undertaking has thus demonstrated the great use which may be made of the submersible motor pumps in places where an installation of ordinary pumping plant would be impracticable, or, at any rate, very costly.—From *Colliery Guardian*, London, January 16, 1920, p. 173.

NEW METHOD OF MEASURING HEAVY DIRECT CURRENT.

THE usual method of measuring direct current with a millivoltmeter and shunt becomes unsatisfactory whenever the measuring instrument is at a considerable distance, 200 yards or farther, from the heavy current cable: the leads must be of large cross-section in order that the drop in them may be a minimum; even then the voltage drop which must be provided across the terminals of the shunt is so high that there is a serious loss of energy in the shunt. If measurements are to be over still longer distances, the cost of pilot leads and the loss in the shunt become almost prohibitive.

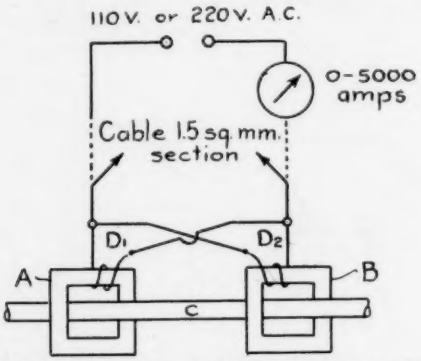

FIG. 3. METHOD OF MEASURING HEAVY DIRECT CURRENT

In order to overcome these difficulties, reliance has been placed in the past upon telephonic communication of instrument readings, or upon the use of repeating instruments of various kinds.

A novel method of measuring heavy direct currents at a distance has been devised by Ernst Besag and is now in use at Frankfort-on-Main. The method depends upon change in the choking effect of a choking coil fed with alternating current, when the iron core of the coil is magnetized by the direct current to be measured as well as by the alternating current.

Referring to the diagram, the heavy-current conductor, C, is surrounded by two iron ring-cores, on which are wound the coils D_1, D_2. These coils are connected so that there is no resultant effect on the current in C due to transformer effect from the alternating-current windings. The terminals of the latter are connected to the distant station, as shown and an alternating-current ammeter is placed where the current indications are required; A. C. supply at 110 volts or 220 volts is connected to the measuring circuit. When there is no current flowing in C, the coils D_1, D_2 exert an almost pure choking effect, and the A. C. ammeter reads practically zero. As the current in C increases, so does the magnetic saturation of the cores A and B, hence the choking effect of D_1, D_2 decreases, and the alternating current in the measuring circuit increases. For each value of the main direct current there is a definite value of the alternating current, hence the A. C. ammeter may be calibrated to read directly the direct current in amperes. By using a pressure of 110 or 220 volts in the A. C. circuit, the requisite current may be kept so low that quite small leads may be used without introducing any appreciable error from the voltage drop in these conductors.

Apart from its value in long distance measurement the new method eliminates the shunt losses, affords the possibility of the pilot lead to be insulated only for 110 or 220 volts and reduces operating risks by eliminating direct electrical connection between the switchboard and the high-voltage D. C. circuit. An important possible application of the new method is to the measurement of charging or discharging current of cells in a distant battery substation.

A possible modification of this method which suggests itself would be to use a single iron core round the heavy D. C. conductor, say, A, of diagram, and to connect a winding D, on this core to a fluxmeter. The fluxmeter being set to zero when no current was flowing in C, the deflection of the instrument should be a function of the current flowing in C. The flow would not be linear owing to magnetic saturation of the iron core, but it would be practicable to calibrate the fluxmeter to indicate directly the corresponding value of the main current. This modification would not be applicable to long distance measurement, owing to the very small E.M.F.'s produced by changes in the magnetization of A, but it may have its application in certain special cases, and, if so, it would offer the advantage of eliminating the A. C. supply required by Besag's method.—From *Elektrotechnische Zeitschrift*, Condensed in *Electrical Review*, London, March 5, 1920, p. 292.

MAGNETIC AND ELECTRICAL PROPERTIES OF IRON-NICKEL ALLOYS.

THIS investigation was undertaken to determine whether any iron-nickel alloys could be found having a higher saturation value than pure iron. Alloys were prepared containing 0-100 per cent of nickel. Pure Fe-Ni alloys do not forge readily, and to make them forgeable it is necessary to add alloying elements like Mn or Ti. The results show that the saturation value decreases slowly with increase in Ni content up to 20 per cent, then rapidly to 30 per cent; again rises rapidly to 50 per cent and falls off gradually toward 100 per cent nickel. At no point does it exceed that of pure iron. For values of H between 100 and 400 the permeability is about 5 per cent higher for 6 to 8 per cent Ni than for pure iron, but this advantage is offset by the large increases in hysteresis loss. Alloys containing 35 to 70 per cent Ni have high permeability at low and medium densities and low hysteresis loss, the highest permeability occurring for 50 per cent. 30 to 50 per cent alloys are characterized by a nearly straight line B-H curve from the origin to B = 2,000 to 4,000 gausses and also by low retentivity and coercive force properties which are of value in connection with certain electromagnetic meters.

Previous investigations on commercial iron-nickel alloys have shown that 25 to 35 per cent alloys have irreversible magnetic and electrical transformation points occurring below ordinary temperatures. The present investigation confirms these results for pure alloys. A 30 per cent alloy annealed and cooled to room temperature had its saturation value, $4\pi I_s$, increased from 2,500 to 17,000 gausses and its electrical resistance decreased from 81 to 32 microns per cu. cm. after being cooled to liquid air temperature and reheated to room temperature. Alloys containing 15.35 and 15 per cent nickel showed practically no change after the above treatment. After allowing all transformations from the austenetic state to the α state to take place the curves for $4\pi I_s$ and for electrical resistances both have definite cusps for 34.5 per cent nickel, corresponding to the compound Fe_2Ni, thus giving evidence of the existence of this compound. It is pointed out that the irreversible transformation causes an enormous increase in the hysteresis loss.—T. D. Yensen, *Journal of the American Institute of Electrical Engineers*, April, 1920, pp. 396-405.

CENTRAL-STATION SERVICE FOR FARM LIGHT AND POWER.

ACCORDING to estimates by Professor G. F. Warren, of Cornell University, the abandonment of farm life in favor of city life by men and boys during the past year has left more than 24,000 habitable farm houses vacant in New York State alone. This exodus from the farm has taken place despite the fact that farm wages will be approximately 14 per cent higher this year than last. It is evidently the city comforts in general and the electrical comforts or conveniences in particular that are largely responsible for people leaving their farm homes. The leadership of this country in world industry depends largely upon the number of progressive farmers who take up and continue modern methods of agriculture. American farms of the future must be equipped with electrical devices if they are to retain the high standards of living we now enjoy. Modern farms will appeal to the brightest of our youth and insure that the direction of the farms will be in competent hands.

The problem of supplying light and power to rural consumers from transmission lines may be considered as being just graduated from the experimental stage. Indications are that a large number of central station companies intend to do extensive work in this field during 1920. Behind it is the insistent demand of the farmer for such service who has seen the drawbacks of the small individual plant and the advantages of the transmission line service whenever the extension of this service is possible. The advantages claimed for transmitted power in comparison with individual plant include less ultimate investment, unlimited supply of power, 24-hour service, use of standard 110-volt appliances, no attention required, no house or barn space required, no acid fumes, smoke, gas, dust or noise, and no oil or gasoline to explode or catch on fire.

The problem, however, is to finance the installation of lines and to make their operation a success; that is to provide lines and equipment at a moderate price and so operated that they will not interfere with the service to municipalities. In the past the central station has financed the entire operation and assumed all risks when setting the rates. Experience has shown that those rates were usually set too low, with a consequent dissatisfaction with this class of service. The established practice at present is to require the farmer to finance the installation lines and the substation equipment. Risks are eliminated wherever possible and the rates set high enough to cover the balance of the contingencies. The tendency is to meter on the high-tension side so as to eliminate the uncertainty of the core losses and their effect on the rate schedule. The country banker must learn to extend credit by virtue of which the farmer can purchase these electric labor saving devices and conveniences, for by so shouldering the responsibility on the farmer, this field becomes financially possible.

OPERATING FEATURES OF FARM LINES.

With the responsibility shouldered on the farmer the equipment must be inexpensive but by no means cheap. The line construction is substantial so as to reduce the chance of line failure resulting in service interruption and liability for injury. The type of construction adopted, while not considered good enough for the more important trunk lines, is nevertheless very satisfactory for farm line service. As to primary pressure, voltages of 2,300, 6,600 and 13,200 have come into extensive use. Experience shows that the 2,300 and even 6,600 are too low, as the extension of farm lines naturally leads to the serving of small towns. It now appears that the standard line voltage for rural service will be 13,200. The farmer will finance the latter as readily as a lower voltage line. The advisability of using the higher line voltages may be seen from the fact that with 6,600 volts an area is served which is approximately nine times the size, and with 13,200 volts an area approximately thirty-six times the size of the area that can be served with 2,300 volts. As to systems, the ground single-phase type, the metallic single-phase and the three-phase four-wire systems have been tried and found unsatisfactory. The three-wire three-phase system has been extensively used and undoubtedly is the most satisfactory one. A combination of this system for the main artery and metallic single-phase lines for short laterals is the logical system to use. This system gives less severe operating conditions for fuses, oil switches and lightning arresters and has the advantage that it can be operated temporarily with one wire grounded. It, therefore, requires less tree trimming, which is quite a factor in rural service.

The question of farmers' substations is perhaps more important than other problems of line construction. As the farm lines are extended the importance of continuous operation becomes more pronounced. In the past this factor has often caused central-station companies to refuse service to farmers even with a line running in front of their homes. With a substation properly designed the fear of the hazard of interference with the continuous operation of the line is dispelled. The requirements of farmers' substations are as follows: (1) It must be inexpensive, but not cheap. (2) While inexpensive it must perform all the functions of a larger outdoor substation with a reasonable factor of safety. It must have full switching, lightning protection and overload protecting features. It must operate with the same degree of security against service interruption, but in case of failure it must be discontinued at once from the line in order that the trouble may be localized and prohibited from disturbing the whole system. (3) It must be safe; there should be but very little wiring and it should be so arranged that when the switch is open all equipment is readily accessible. (4) The factor of safety of the insulators should be high.—H. W. Young and F. C. Van Etten in *Electrical Review*, Chicago, March 20, 1920, pp. 483-85.

ELECTRICALLY-BAKED BREAD.

IN localities where coal or other forms of fuel are scarce or dear the electric oven can be considered a serious competitor to the coal-heated oven. Electric ovens are on the market which are entirely satisfactory from the standpoint of technique, ease and safety of operation; moreover, the central station grants the baker very low rates for night operation of his electric ovens. In Switzerland the electric oven usually has an area of 6 or 12 sq. m. per floor, giving space for 16 to 18 kg. of bread per square meter. With loaves weighing from 0.5 to 1 kg. the baking takes one hour; with loaves weighing 1.5 to 2 kg. the baking period is one hour and a quarter to one hour and a half. The average amount of power required is 6 kw. per sq. in.; this permits the heating of an oven of $12m^2$ in area in 1½ hours. During the baking period the power consumed varies from 50 to 60 per cent of that used for preheating. Below are given some data for one installation.

Hours of operation	Kg. of bread	Kw.	—Kw.-H. consumed— Total	Per Kg. of bread
1.5		72	108	
3.25	200	36	171	0.86
5	400	36	234	0.59
6.75	600	36	297	0.50
8.5	800	36	360	0.45
10.25	1,000	36	423	0.42
12	1,200	36	486	0.41

The manufacturers guarantee a consumption of 0.45 to 0.5 Kw-h. per kg. of bread. The initial cost of installation in 1918 was from 1,200 to 1,500 fr. per square meter—not any higher than for a first-class modern steam operated oven. It is further estimated that with coal selling at 10 fr. per kg. and electricity selling during night hours at 0.05 fr. per kilowatt-hour, economies will be effected with the electric oven.—From *Bulletin de l'Association Suisse des Electriciens.* Abstract in *Revue Générale de l'Electricité*, January, 1920.

Survey of Progress in Mechanical Engineering

Prepared Under the Auspices of the American Society of Mechanical Engineers

AMERICAN COMPETITION WITH BRITISH TRADE.

THE subject is discussed in *Engineering* (London) in an editorial under the title, "The Question of American Competition."

The paper calls attention to the sales efforts of American concerns in Europe, such as the fact that a leading American locomotive firm is alleged to have sent a representative to The Hague where he offered to quote prices not only on locomotives and other railroad equipment but also for all kinds of machinery including machinery for treating sugar, rubber, coffee and cocoanuts in tropical countries.

On the other hand, it is stated that in the calendar year of 1919 the American exports decreased while the imports increased, the reduction being due to the fall in the quantity of semi-finished steel sent out of the country for the account of Allied nations.

The imports increased through purchases of scrap and pig iron. (The statistics refer, of course, exclusively to the metal and machinery trades.)

If the American statistics are contrasted with those for Great Britain, it is found that the British exports showed a recovery for the first year after the end of active hostilities. The exports rose from 1,618,000 tons in 1918 to 2,254,000 tons in 1919, being an advance of 636,000 tons, giving a net balance of 360,000 tons to the advantage of Great Britain. The figures in the case of machinery are also hopeful for Britain, although a strict comparison between the latter and the United States cannot be made. The British exports advanced in tonnage by 65 per cent as compared with the preceding year.

As regards the future, it is stated that American steel and machinery makers have secured a great hold on international markets under the abnormal circumstances of a world-wide war and thereby became abnormally enriched. Furthermore, though peace prevails, the conditions throughout the world have not become normal and probably will not do so before another few years have elapsed. There is a great international demand for iron, steel and different classes of machinery in various countries and it is believed that Great Britain will obtain its fair share of this world trade as in former years. In fact, figures appear to show that it has already been able to make a fresh and favorable start in the resumption of its former position in the markets of the world, though the present high prices tend to facilitate American competition in external markets, except where the rate of exchange exercises an unfavorable influence upon prospective customers. Nevertheless the amount of work available in the world is so enormous that international competition to secure it should be inconsiderable for a long time to come.—*The Engineer*, Vol. 129, No. 3349, March 5, 1920, pp. 249-250.

NO FISSURES IN OLD RAILS.

A REPORT by W. C. Cushing, Chief Engineer of Maintenance, Pennsylvania Lines West of Pittsburgh, gives an interesting sidelight on the cause of the appearance of transverse fissures.

This report covers an investigation of rails which had been in service from 10 to 45 years; some of the oldest were of wrought iron, others rolled from iron and steel pile, while others 10 to 25 years old were of Bessemer steel.

In the old wrought-iron rails, head strains corresponding to 24,000 to 27,000 lb. per sq. in. in compression were found, which appeared the more serious because the material had a low elastic limit, 26,670 to 48,760 lb. per sq. in. The piled rails showed maximum head strains of 24,000 lb. per sq. in., and the elastic limit of the material ranged from 33,700 to 58,830 lb. per sq. in. Still higher internal strains, however, were found in steel rails that had been in service 20 to 25 years, several measurements of 36,000 to 33,000 lb. per sq. in. being made, as against elastic limits of 46,500 to 58,450 lb. per sq. in. These high values of permanent strain were measured at the surface of the head and on the side opposite the gage side, in nearly every case. One abnormal result was a reading of 57,000 lb. per sq. in. tensile stress, in the flange of an 85-lb. rail that had been in service from 1898 to 1917; Mr. Cushing calls this "extraordinary and inexplicable."

From a knowledge of the service to which these rails were submitted one would expect to find them filled with transverse fissures. In fact rails adjacent to them and undergoing precisely the same condition of service had been found to contain such fissures, which would indicate that the difference in the behavior of the two classes of rails must be sought in the process of manufacture.—Report No. 84 to the Rail Committee of the American Railway Engineering Association, abstracted through *Engineering News-Record*, Vol. 84, No. 11, March 11, 1920, p. 527.

AERIAL TRANSPORT OF WOOLEN GOODS.

OWING to the congestion of traffic at Hull Docks and to the dockers' strike at Amsterdam, the transport of goods from the Midlands to Holland, which has been taking the preposterous time of from six to eight weeks, has, for the meantime, become quite impossible. For this reason Messrs. Heatons (Leeds), Ltd., who do considerable business with Holland in ladies' clothing, decided to despatch by aeroplane a quantity of goods which they were anxious to deliver in Holland in time for the spring season. A Blackburn "Kangaroo" commercial airplane was therefore chartered from the North Sea Aerial and General Transport Company, of Leeds, to convey 22 packages, with an aggregate weight of over 1000 lb. to Amsterdam. The machine was loaded at Brough aerodrome, near Hull, on Friday, March 12th, and proceeded to Lympne, near Folkestone, for examination by the air-port authorities and thence to Soesterberg aerodrome at Amsterdam, where it arrived safely on the following day. The Dutch customs authorities arranged to examine the cargo immediately on its arrival, so that the packages could be despatched to their final destinations with little or no delay. The machine was expected to return with a valuable cargo of dyes of a class urgently required in Yorkshire and Lancashire. It is hardly necessary to point out that the commercial value of the service would be greatly augmented if the visit to Lympne for customs examinations could be avoided. Lympne is, at present, the only recognized point of departure for Continental aerial traffic, and this fact is obviously a severe handicap on aircraft travelling from the northern counties to Holland and the Baltic. Evidently the traffic would be greatly facilitated by Government recognition of an air station on the North Sea coast, since a direct flight across the North Sea could be made in half the flying time, and in much less than half the total time, owing to the fact that the long southward diversion renders a night's stay at Lympne unavoidable.—*Engineering*, Vol. 109, No. 2828, March 12, 1920, p. 344.

RELIEVING ATTACHMENT FOR LATHES.

IT is usually considered to be uneconomical to make milling cutters and other small tools in a general engineering shop,

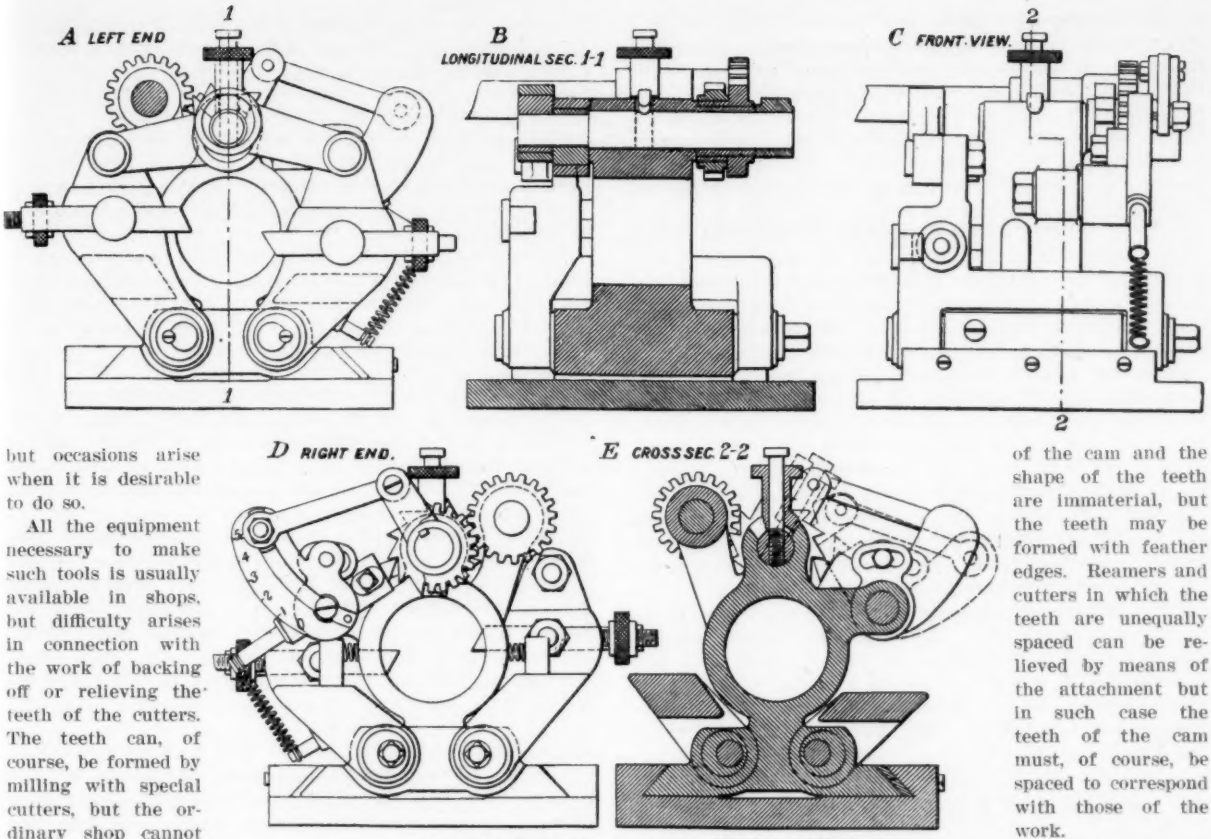

FIG. 1. MILTON RELIEVING ATTACHMENT FOR LATHES

but occasions arise when it is desirable to do so.

All the equipment necessary to make such tools is usually available in shops, but difficulty arises in connection with the work of backing off or relieving the teeth of the cutters. The teeth can, of course, be formed by milling with special cutters, but the ordinary shop cannot have all the cutters required for different shapes and sizes of tools. A relieving lathe which might be employed is likewise an expensive tool of very little general utility and it would not pay to have one to take care of an occasional odd job.

From this point of view the attachment described here and built by Milton, Ltd., London, is of interest. It is intended to take care of just the kind of job that can be usually done only on a relieving lathe or by means of special tools.

Drawings, Fig. 1—A to E, illustrate the construction of the attachment. It is mounted on a gibbed plate which is screwed upon a lathe saddle. Into this plate is fitted a steel casting having a hole through which the work passes, or the arbor on which the work is mounted between the centers of the lathe. There are also two oscillating tool posts carrying tools which can operate simultaneously on the front and back of the work, though for relieving, the front tool only is employed. Provision is made for adjusting the tools in a vertical direction to allow for any alteration in height which may have been introduced by grinding—likewise for the transverse adjustment of the tools. The tools themselves fit in slots in the tool posts and are each clamped in position by a bolt and nut.

The tool posts are rocked by means of two eccentrics mounted on a central shaft passing through the upper part of the main casting as shown in Fig. B. These eccentrics which are connected to the tool posts by means of short links shown in A are set at an angle of 180 deg., so that angular motion of the shaft will cause both the tool posts to advance into or recede from the work together. Mounted loosely on the opposite end of the central shaft bearing is a gear wheel, and on a sleeve extending from the boss of this wheel is screwed a ratchet toothed cam seen in Figs. A and D. The cam is driven from the nose of the lathe by means of a shaft having two universal joints. The cam rotates at the same speed and in the same direction as the work and must have the same number of teeth as the tool being relieved. The actual diameter of the cam and the shape of the teeth are immaterial, but the teeth may be formed with feather edges. Reamers and cutters in which the teeth are unequally spaced can be relieved by means of the attachment but in such case the teeth of the cam must, of course, be spaced to correspond with those of the work.

Referring now to Fig. D. (in Fig. 1) it will be noticed that the teeth of the cam engage with an adjustable pawl mounted on one arm of a bell-crank lever, which is pivoted on the main casting. As the cam rotates in an anti-clockwise direction the arm of the bell-crank lever will be pulled downwards until the pawl escapes from the tooth of the cam, when it will be pulled up into engagement with the next tooth by the action of a light helical spring seen in both illustrations. The combined effect of the cam and spring is thus to impart an oscillating motion to the bell-crank lever. On the other arm of the latter is formed a segmental groove, and in this groove a block, to which a short link is pivoted, can be clamped in any position. The other end of the link is connected to an arm keyed upon central shaft, above referred to, and in this way the oscillating motion of the bell-crank lever is communicated to the central shaft, and also, through the eccentrics, to the tool posts. Two short springs fitted between projections on the forked parts of the tool posts and the main casting are provided in order to take up any lost motion due to wear of the links, etc.

It will be obvious that the position of the block in the segmental groove determines the magnitude of the angular oscillations of the central shaft, and consequently those of the tool posts, so that, by adjusting the block, the amount of relief can be varied at will quite independently of the shape of the cam. The actual amount of relief is indicated by a scale engraved on the arm of the bell-crank lever, as shown in Fig. D, the figures giving the amount of relief in millimeters. The only other feature of the mechanism now remaining to be explained is the means provided for limiting the backward movement of the tools in normal working, while allowing them to be brought back clear of the work before reversing the motion of the saddle to commence a new cut. This arrangement is best shown in the cross-section, Fig. E, from which it will be seen that a bolt fitted with a sliding sleeve is screwed

into the middle of the central shaft. A tongue formed on the sliding sleeve fits into a slot in the main casting, and normally limits the movement of the shaft by coming into contact with the end of the slot, but when it is desired to withdraw the tools from the work the tongue is pulled out of the slot by raising the sleeve. This allows the spring attached to the bell-crank lever to pull the latter back into the position indicated by the dotted lines in Fig. E. In this position the tools will be quite clear of the work and the pawl clear of the cam; the lathe can then be reversed without altering the adjustment of the tools in the tool holders.

An important advantage of the pivoting tool holder in comparison with the horizontal slide of the ordinary relieving lathe, is that, in the former, the tools can be adjusted so that the cutting angle remains constant at all parts of the cut, and consequently greater cutting efficiency is attained and a tool with much less clearance can be used. That it is necessary to tilt the tool for this purpose will be obvious when it is remembered that the normal to the relief curve at the cutting edge of the tooth being formed coincides with the radius of the plain cylindrical blank, since no metal is removed from this part of the tooth, whereas, at the inner end of the curve, the normal is inclined by an amount depending upon the amount of relief. In an ordinary relieving lathe, in which the tool moves horizontally, no allowance is made for this feature, and the cutting angle may therefore vary by 15 deg. or 20 deg. from one end of the relief curve to the other. Another advantage of the pivoted tool holder is that the friction is considerably less than that of a sliding holder, and a greater part of the power supplied is available for the cut.—*Engineering*, Vol. 109, No. 2828, March 12, 1920. pp. 345-346 and 348.

THE HOLZWARTH GAS TURBINE SINCE 1914.

By Hans Holzwarth.

In 1914, a few months before the beginning of the war, tests were started on a 1000-h.p. vertical gas turbine built by the machine company, Thyssen & Co., in Mulheim (Ruhr). During the war these tests were discontinued and started over again in 1918. The Thyssen turbine does not differ in external appearance from the gas turbine previously built by the author at Mannheim, but in several particulars the Thyssen turbine differs from the Mannheim one.

HIGHER CHARGE AND EXPLOSION PRESSURES.

This was done to increase the output per cubic unit of chamber capacity and the thermal efficiency. The average explosion pressure for continuous operation was raised to from 12 to 14 atmos. abs. as compared with 5 to 6 atmos. abs. of the Mulheim turbine.

There is fundamentally nothing in the way of raising this pressure still higher by increasing the charge pressure above 2.3 atmos. abs. The curve of Figs. 2 and 4 show the influence of the charge pressure and explosion pressure on the efficiency and specific output of the turbine.

REDUCTION OF THE PERIOD OF EXPANSION.

The shorter the time taken by expansion the less the loss of heat to the chamber and nozzle walls and the greater the amount of heat transformed into kinetic energy, and, hence, the greater the efficiency. At present the duration of the period of expansion in the gas turbine is around 0.1 sec. In large gas engines running at 90 r.p.m. the expansion lasts about 0.33 sec., while in aircraft engines in which the heat consumption is not materially inferior to that in Diesel engines, it is 0.02 sec. at 1500 r.p.m. Fundamentally, there is nothing in the way of reducing the expansion period in the gas turbine still more. To do this the nozzle cross-section must be increased and this carries with it the increase in the length of the turbine blades and flow resistance.

CHANGES IN THE BLADE SHAPES AND BLADE FASTENINGS.

Decrease in the period of expansion provides an increase in pressure on the blades. Furthermore, unlike what takes place in steam turbines, the jet in explosion turbines acts intermittently for short periods and is of the character of a blow. Because of this, blade shapes and fastenings used, for example, in Curtis turbines would not be satisfactory. New blades, therefore, had to be developed which were planned to withstand the added stresses much better.

As regards the material of the blades, many kinds of al-

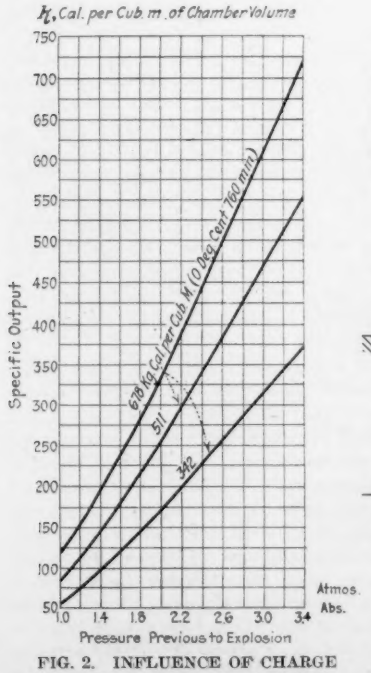

FIG. 2. INFLUENCE OF CHARGE PRESSURE ON EFFICIENCY

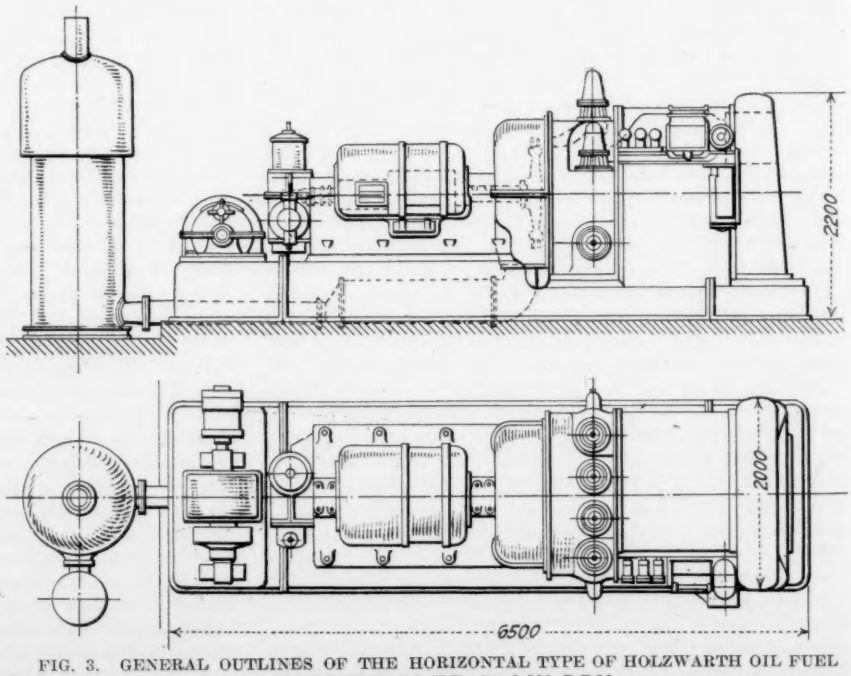

FIG. 3. GENERAL OUTLINES OF THE HORIZONTAL TYPE OF HOLZWARTH OIL FUEL GAS TURBINE 500 H.P. AT 3,000 R.P.M.

loyed and unalloyed hard and soft steels were tested with rather unsatisfactory results, and finally a soft electrolytic iron was adopted. With proper heat treatment blades of this iron proved to be very satisfactory for use in gas turbines. Table 1 shows the physical properties of this material from tests made in the testing laboratory of the Technical High School at Stuttgart.

On the other hand, blades made out of harder or alloyed steels show very rapidly changes in the structure of the metal,

Table 1

PHYSICAL PROPERTIES OF ELECTROLYTIC IRON USED FOR GAS TURBINE BLADES.

	—Tested at— Room Temperature	450 deg. Cent.
Yield Point .....kg. per sq. cm.	4204	
	3185	1975
Breaking Load .....kg. per sq. cm.	4510	2675
Elongation .....per cent	27.2	50.2
Contraction .....per cent	73	88.4

cracks and fissures. Electrolytic iron in gas turbine blades appears to be quite able to withstand wear and also resistant against surface corrosion and erosion, provided, however, no substantial amounts of wet steam or water are present in the gases of combustion.

NOZZLE SHAPES.

DeLaval nozzles and nozzles with parallel exit walls were tested as well as several other shapes. The advantage of nozzles with parallel walls which lies in their offering a greater cross-section of exit is counterbalanced by an increase in deflection of jet and on the whole it was found that steam turbine experience applies within reason to the design of gas turbine. Most satisfaction was obtained with DeLaval nozzles with minimum possible angle of exit just as in steam turbine practice.

Practical experience has confirmed theoretical expectations to the effect that the reduction of heat fall during the expansion does not materially affect the efficiency of the gas turbine nozzles and blading. For example, if the instantaneous maximum jet velocity at the beginning of expansion is in the neighborhood of 1500 m. per sec., more than 95 per cent of the mechanical energy of the gases of combustion are available at the wheel up to the time when the jet velocity sinks to about 1000 m. per sec. This means that more than 95 per cent of the energy is available at jet velocities varying 19 per cent either way from the average jet velocity for which the nozzle and blading have been designed. Practical experience confirms these theoretical considerations. Time after time useful efficiencies of about 55 per cent (i.e. about 55 per cent of the output attainable in a gas turbine free from all losses) have been indicated in the periphery of the wheel.

In steam turbine practice the upper and lower limits in the heat fall process are determined on one hand by the initial pressure and temperature of the steam, and on the other hand by the vacuum in the condenser. Furthermore, the peripheral velocity of the rotor is also predetermined and all that the designer can do is to rearrange the stages one way or another. In gas turbines the lower limit of the heat fall is predetermined and for practical purposes so are the peripheral velocity and number of stages. On the other hand, however, the designer is free to vary the upper limit of the heat fall and through this the important ratio (jet velocity ÷ peripheral velocity) without materially affecting thereby the thermal efficiency of the turbine.

CHANGE IN NOZZLE VALVES.

The employment of higher charge pressures and the increase in the cross-section of the nozzles required some changes in the design of the nozzle valves which are described in a very general manner.

TESTS.

The tests were carried out in the presence of various railroad officials in December, 1919. Coke-oven gas was used as fuel with the heat content of 3860 k.cal. per cu.m. The turbine was driving a dynamo delivering current to a water rheostat. The main test lasted four hours and gave the results shown in Table 2.

Table 2.

DATA OF TESTS OF HOLZWARTH-THYSSEN GAS TURBINE.

Gas Consumption, reduced to 0 deg. cent., and 760 mm. mercury pressure, cbm. per hour	300	400	550	630
Heat supplies, cal. per hour..	1,150,000	1,530,000	2,110,000	2,415,000
Power output at wheel η_{umf}. horse-power	70	251	724	984
Heat consumption, k. cal. per h.p.-hour	16,430	6,090	2,915	2,450
Efficiency η_{umf} per cent....	3.9	10.4	21.8	26

Figs. 5 and 6 give the amounts of heat delivered to the turbine per hour, and the efficiency η_{umf} refers to the power output η_{umf} delivered by the wheel. The work consumed in compressing the blast air and gas amounted to about 5.7 per

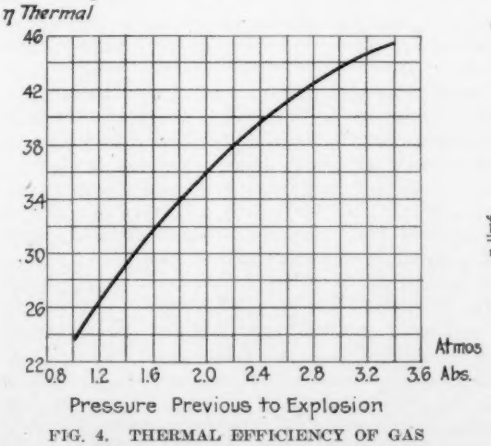

FIG. 4. THERMAL EFFICIENCY OF GAS TURBINE AS A FUNCTION OF CHARGE PRESSURE PREVIOUS TO EXPLOSION (PRODUCER GAS FUEL OF HEAT VALUE 500 CAL. PER CU. M.); TEMPERATURE OF MIXTURE 77 DEG. C.

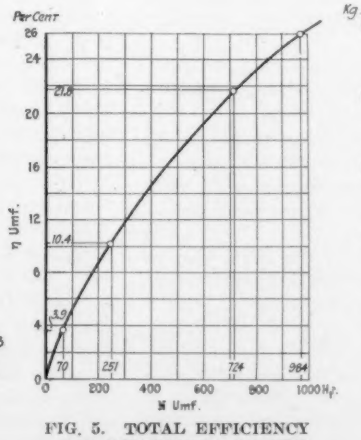

FIG. 5. TOTAL EFFICIENCY (AS MEASURED) ON THE WHEEL PERIPHERY AS A FUNCTION OF THE POWER OUTPUT INDICATED AT THE WHEEL

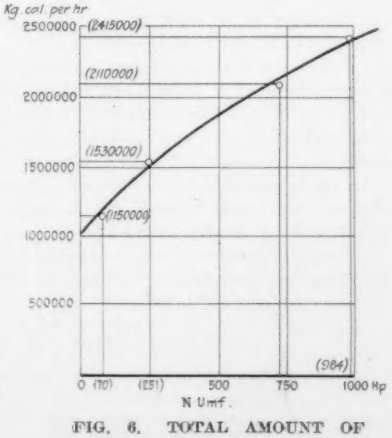

FIG. 6. TOTAL AMOUNT OF HEAT SUPPLIED AS A FUNCTION OF THE POWER OUTPUT AT THE WHEEL OF THE HOLZWARTH OIL FUEL GAS TURBINE

cent of the exhaust heat. If the efficiency of the compressor be assumed to be 70 per cent, of the condenser steam turbine 18 per cent and utilization of exhaust heat 60 per cent, then the total efficiency for the exhaust heat plant and the blower system is $0.70 \times 1.19 \times 0.16 = 7.6$ per cent, in which case the power consumption for the blowers can be well taken care of by exhaust heat.

CONSTRUCTION.

Gas turbines of the horizontal type appear to be preferable in several important ways to vertical turbines, and it is intended in the future to build only horizontal gas turbines. Fig. 3 shows the general oultines of a 500-h.p. oil-fuel gas turbine now under construction to run at 3000 r.p.m. and drive a direct-current generator. The blower and exciter generator are built on the same base as the main engine, and directly connected thereto are the exhaust fuel heated boiler delivering steam for the blowers. This installation is to go to the Prussian Railway Administration. The same article gives an illustration of a 12,000-kw. gas turbine which seems, however, to be only in the design stage as yet.—*Zeitschrift des Vereines Deutsche Ingenieure*, Vol. 54, No. 9. Feb. 28, 1920, pp. 197-201.

Progress in Mining and Metallurgy

Summary of Important Papers

Prepared Under the Auspices of the American Institute of Mining and Metallurgical Engineers

THE OIL FIELDS OF RUSSIA.

By A. BEEBY THOMPSON, London, England.

FOR more than 2500 years, natural gas issues in the Surakhany district of the Apsheron peninsula were the object of pilgrimages by fire worshipers and Hindoos from Burma and India.

Within a few miles of Baku lie the two richest oil fields in the world, viz., the Balakhany-Saboontchy-Romany and the Bibi-Eibat. For many years the gasoline obtained in the refineries of the Baku area was burned in pits, being considered an undesirable product; and until 1870 the residue also was destroyed, its value as a fuel not being recognized. Kerosene was the main product sought by the refiners.

In 1903 the important Grosny oil field was proved by a great flowing well sunk by an enterprising Englishman, who, however, was ruined by the claims for compensation made by peasants whose habitations and lands were destroyed by the deluge of oil, which could not be controlled for years. The property on which the well was drilled has since given over 300,000 bbl. of oil per acre.

In 1901, general interest was directed to the Binagadi oil field by the bringing in of a 10,000-bbl. well.

Another interesting field is Holy Island, off the north coast of the Apsheron peninsula, where 400-bbl. wells have been struck and a considerable area has been proved to be oil-bearing. In 1908, the Surakhany district a few miles southeast of the main Saboontchy oil field was developed by deep wells, and large gushers of the typical Baku oil resulted from beneath the upper light oil and gas-yielding beds that until then had been exclusively worked.

In 1909, the Maikop oil field attracted considerable attention as the result of a large gusher of light oil being struck by almost the first trial well in the Shirvansky district.

A promising oil field was developed, about 1910, in the Emba district north of the Caspian Sea and inland from the port of Gurieff. Around Dossor, large flowing wells were struck, and, prior to the war, extensive arrangements were being made to dispose of the product.

A single Tukestan field, in Fergana on the Trans-Caspian Railway at Chimiono, has yielded substantial supplies of oil that find ready local market.

OIL MANIFESTATIONS AND GEOLOGY.

No country in the world probably exhibits a greater display of oil field surface phenomena than Russia. There are thousands of square miles flanking the Caucasus Mountains and encircling the Caspian Sea that justify an investigation. For miles around the Baku oil fields, the oil series lie spread out like leaves of a book under the nearly desert-like surroundings of that devastated region. Mud volcanoes on a gigantic scale in every stage of activity may be witnessed, as well as perpetual fires fed by incessant issues of natural gas. Acres of asphaltic residues and streams of viscous oils oozing from immense thicknesses of oil-soaked sands are common. These phenomena, mingled with sulfurous waters, present problems for study that are nowhere else reproduced on so large a scale.

Comparatively simple partial domes characterize the two great oil fields of Baku, but both have flanks on one side where the oil-bearing series outcrop and display those surface phenomena usually associated with oil. The whole series of Tertiary strata in which the oil is secreted here consists of unconsolidated clays, sandy clays, and sands of all grades of fineness that readily break down and crumble when pierced by the drill. Their fragile nature is the cause of unusual difficulties in drilling, as throughout a thickness of over 3000 ft. there are constant irregular and ill-defined alterations of sands and clays that merge into one another in a way that makes a log very unreliable when prepared from collected samples. Some sands are charged with oil, some with gas alone, and others with oil and gas. Many of the water-bearing quicksands run freely on penetration and fill the hole to a depth of hundreds of feet. At times, too, oil-saturated clays continue to ooze into the well, which renders progress very difficult.

Certain sandy horizons can occasionally be traced for some distance and definite water and oil horizons have been located within restricted areas. Generally, however, the pliable beds have been so contorted and crushed that no single bed can be recognized for any considerable distance. Geological study was always made more difficult by the further disruption the beds sustained when rich oil sands were struck, masses of surrounding strata were expelled on penetrating a rich oil sand, and this was generally followed by thousands of tons of sand which was either ejected with oil during flows or removed with the oil during the later process of its abstraction. As much as 50 per cent sand (by weight) has been obtained suspended in the oil for a time, and often as much as 10,000 tons of sand have been ejected daily and for weeks from a well piercing a virgin and prolific sand body.

DRILLING OPERATIONS AND YIELDS.

Owing to the highly disturbed and unconsolidated sediments in the Baku oil fields it has been found impossible to adopt there the standard American cable system or even the rotary. The need for wells having exceptionally large initial and completed diameters arises from the necessity to exclude waters and penetrate swelling and caving ground during progress, as well as to permit of the extraction of oil by bailers; consequently, the "stove-pipe" class is mostly employed. Initial diameters of 36 in. to 40 in. (91 to 101 cm.) are usual when

ultimate diameters of 12 in. to 14 in. are desired at a depth of 2000 ft. Massive surface gear is necessary to manipulate columns of such size and the tools required.—Abstract of paper to be read at the St. Louis Meeting of the Amer. Inst. of Min. & Met. Eng.

PULVERIZED COAL AT HIGH ALTITUDES.

By Otis L. McIntyre.

THE Cerro de Paslo Copper Corporation, at La Fundicion, Peru, used about 65,000 tons of coke per year, of which about 85 per cent is local coke made at the smelter, and 15 per cent is imported. This latter is very expensive, and as both classes of coke enter largely into the smelting costs, it was decided to experiment with pulverized coal in the various departments of the smelter. The preliminary work consisted in determining the general combustibility of the local coals in pulverized form. The coal was dried by hand on steam hot pans to less than 1 per cent moisture, and then ground in a 4 in. by 4 in. Marcy mill.

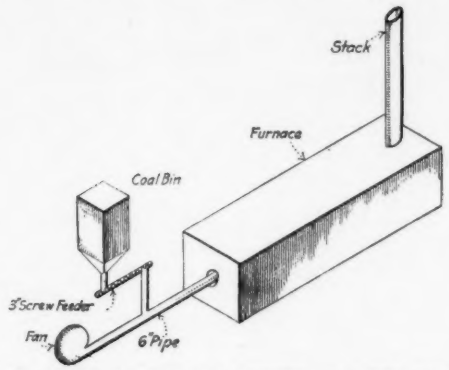

FIG. 1. FIRST LAYOUT OF EQUIPMENT USED IN TEST

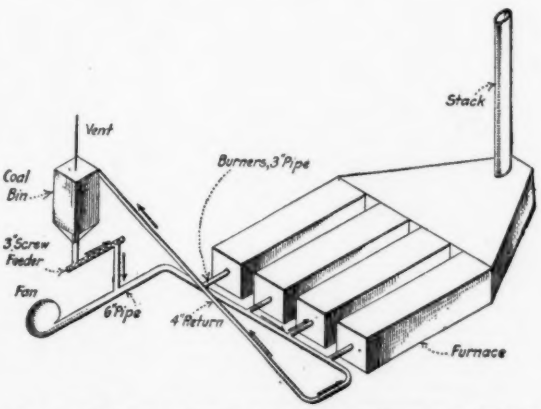

FIG. 2. SECOND LAYOUT OF EQUIPMENT FOR FURNACE TESTS OF PULVERIZED COAL

The equipment used in the test is shown in Fig. 1. It consists of coal hopper, a 3-in. feed screw driven by variable-speed motor, and a No. 2 Sturtevant blower supplying the air. The burner was a standard 6-in. pipe projecting about 12 in. into the furnace, which was approximately 4 by 4 by 16 ft. and constructed of fire-brick. No pyrometric measurements were taken, but observation of the furnace showed the results to be satisfactory.

The tests were first made with pure pulverized coal, and then with mixtures of coal and coke breeze, varying from 10 to 35 per cent of coke breeze, which gave practically the same results as the pure coal. The layout was then changed, as shown in Fig 2, to test the practicability of using more than one burner with a single feeder. This test was run with the 4-in. return pipe both open and closed, the results indicating that satisfactory operation could be obtained by either method with a properly proportioned pipe system.

The next test was to sinter the fine ores on a standard Dwight-Lloyd sintering machine. These machines are oil-fired, and if coal could be substituted a considerable saving would be effected. The equipment used in this test was the same as is shown in Fig. 1, except that a 1-in. screw feeder, a smaller fan, and a 2-in. pipe burner were used. This test produced a satisfactory sinter, though some trouble was encountered in the primary ignition of the coal, and the standard oil muffle was too small.

The next experiment was to test the feasibility of conveying pulverized coal under direct air pressure; the layout used is shown in Fig. 3. Pulverized coal was placed in the pressure tank and air at 20 to 25 lb. was admitted through the ¾-in. pipe at the top of the tank. The 4-in. valve at the bottom was then opened and the coal passed through the 4-in. piping system to the coal hopper. In this way 4000 lb. of coal was transported in 1½ to 2 min. The loss through the vent pipe varied from 100 to 200 lb. This can be remedied by using dust collectors on the hopper, or an exhaust system which would return this waste coal to the main hopper.

The foregoing tests showing up so well, it was decided to erect a larger experimental pulverizing plant.

The furnace performance through all tests was found to be fully equal to that when operating on the normal coke charge. Two difficulties were encountered, namely, keeping some of the feeders in operation and keeping the tuyeres open. In some of the feeders there was a slight back pressure, due probably to partly blocked tuyeres. This did not affect materially the feeding, but forced some coal dust into the feeder bearings, which mixed with the oil and finally bound the bearings. By using dust-proof bearings and a better-designed injector, we expect to eliminate this trouble.

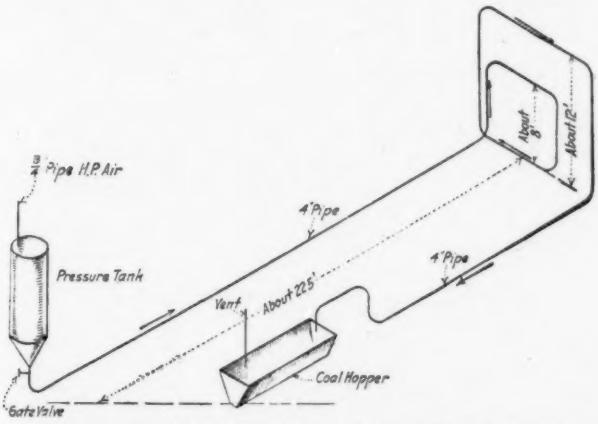

FIG. 3. TEST OF FEASIBILITY OF CONVEYING PULVERIZED COAL UNDER DIRECT AIR PRESSURE

Keeping the tuyers open is absolutely essential to the safe and efficient operation of this process. In view of the difficulty of keeping the tuyeres open and the connections airtight, it is probable that the most satisfactory place to inject the coal into the furnace would be through a separate opening in the jackets, between and somewhat above the tuyeres.

The No. 5 reverberatory was selected for the final test. This test was disappointing from the actual results, but when the following difficulties which were encountered are corrected, the furnace will, beyond question, show a much higher efficiency than the hand-fired furnace. First, the coal could not be dried sufficiently, the average moisture being in excess of 1.5 per cent. The plant would not grind sufficient coal to the required fineness. The discharge from hopper to feeder

was too small, and the coal continually caked and bridged. The screw feeder was too short so that the coal flushed badly at times; also the discharge from the feeder was too far from the fan so that the coal accumulated in the suction pipe and had to be removed with an air jet.

This test covered about nine days, and was run for about two days with the return pipe open. Some time during the second day the return pipe was blocked, due to overfeeding, so it was decided to continue the test without opening the run pipe; the only difference was an apparently heavier feed at the burner farthest from the fan. With a properly designed piping system there seems to be no reason why a series of burners cannot be operated from a single feeder with or without a return. The last day's run of this test was made with a mixture of 75 per cent coal and 25 per cent coke breeze, which gave results equal to straight coal. It may be of interest to note that these experiments and tests were carried out at an elevation of 14,200 ft.—Abstracted from paper to be presented before the American Society of Mechanical Engineers in St. Louis, May 24 to 27, 1920.

OUTLINE FOR ANALYSIS OF OIL-FIELD WATER PROBLEMS.

By A. W. Ambrose, Bartlesville, Okla.

THE underground losses of oil exceed, by hundreds of thousands of barrels, all the oil that has been lost in storage, transportation, or refining. The quantity lost is, of course, indeterminate; but when it is considered that the contents of an entire oil field have been excluded from recovery by invading waters, some idea of the amount wasted may be gained. Similarly, enormous quantities of gas have been lost under ground. Conservation of the oil, therefore, should start before it is brought to the surface rather than after it is placed in storage tanks.

In an area drilled with a hole full of mud or fluid the operator should consider the contents of a sand which has been as an unknown quantity, unless the sand tested in a neighboring well by bailing or pumping. In an area where the hole is filled with water while drilling, the hydrostatic head of fluid in the hole is usually greater than that of the water or oil in the sand, hence oil or water will not come from the sand into the drilling well. Fig. 4 is a hypothetical sketch showing several possible waters in a producing oil field.

Those waters *A* and *A*, occurring in the sand above the producing oil horizon are generally known as top, or upper, waters. Top water may have access to the hole by: The shut-off being too high; the water leaking around the shoe of the water string; poor coupling connections, due to cross-threading or the pipe not being screwed tight; collapsed casing; a split in the casing, pipe worn through by drilling-line wear, or corrosion of the casing due to strong corrosive waters in the sands.

Bottom waters *E* are those occurring in sand below the producing oil horizons. To avoid bottom water, it is necessary to learn the exact distance between the top of the water sand and the base of the oil zone, so that the operator can avoid drilling too deeply.

Where there are several producing oil or gas horizons, the water *C* occurring between the producing sands is generally referred to as intermediate water. (If there are only two producing sands, the term middle water is often applied to the water occurring in a sand between them.)

Edge water *D* occurs in the down-slope portion of an oil or gas stratum. Edge water may be middle water in one well and bottom water in another part of the field. It usually encroaches as production is drawn from the wells up slope. The sand is termed an oil producer up slope, but wells drilled into the same sand down slope will produce water.

Water may occur in the base of an oil sand, although before drawing such conclusions it is advisable to consider carefully whether or not there is a small formational break of an impervious bed between the oil and water. Water, also, may occur in a lenticular body of sand and should be treated as top, bottom, or intermediate water, according to its location with respect to the productive sands.

The flooding of the oil sands of an area by top, bottom, or intermediate water can often be prevented by the correction of a few offending wells when the trouble starts. The operator should, therefore, investigate promptly any marked increase in the water content of a well.

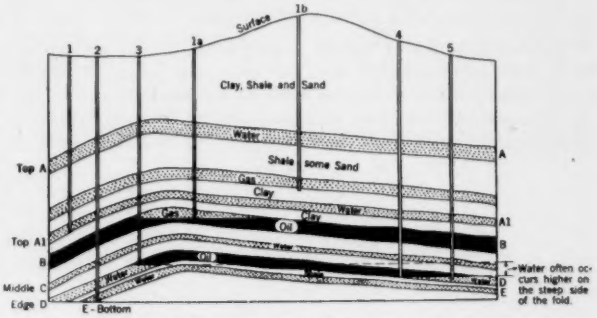

FIG. 4. HYPOTHETICAL SKETCH SHOWING DIFFERENT WATER SANDS

The indications of a field going to water vary with each locality, but the most common and positive evidence is for the oil wells to start producing water. When a group of wells located high up on the structure, for instance on the top of a dome, show water while wells down slope do not, some well is at fault. In such a case the cause may be due to improper water shut-off points, leaky water strings, wells drilled into bottom water, or wells improperly plugged when abandoned. Top water, bottom water, and water in a lenticular sand usually lend themselves to repair work on the wells.

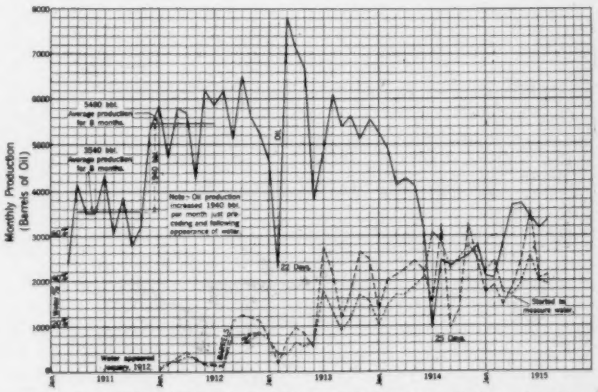
Monthly Production (Barrels of Oil)
5480 bbl. Average production for 8 months.
3540 bbl. Average production for 8 months.
Note - Oil production increased 1940 bbl. per month just preceding and following appearance of water.
42 Days
25 Days
Started to measure water
Water appeared January, 1912
1911
1912
1913
1914
1915

FIG. 5. INCREASE IN PRODUCTION OF OIL WELL PRIOR TO ENCROACHMENT OF EDGE WATER

Water in the base of an oil sand and edge water presents a much more serious problem, for as the oil and gas are withdrawn they will be replaced by water. Water in the base of an oil sand often occurs in abundant quantities; if a hole is carefully plugged up with cement the water production is only temporarily retarded. When the wells farthest down slope, located along a line parallel in general to the underground contours, show an increased water content, there is suspicion of the encroachment of edge water.

A sudden increase in oil production has been noticed in wells just before edge water appears. This is shown in Fig. 5. It will be noticed that the average production per month was 1940 bbl. more following the appearance of water in appreciable quantities in January, 1912.—Abstract of paper to be read at the St. Louis Meeting of Amer. Inst. of Min. & Met. Eng.